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SCIENTIFIC FAITH AND WORKS[1]

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THE ancient poets, at the beginning of their great epics, invoke the muse, and forthwith proclaim their subjects:

Arma virumque cano, I sing of arms and the man, says Virgil, Μῆνιν ἀείδε θεά—Achilles' baleful wrath, O Goddess, sing, are the words with which Homer begins the Iliad. A modern poet, full of sympathy with the changed times of to-day, Rudyard Kipling, makes one of his most attractive characters, the old Scotch engineer, exclaim,

> I'm sick of all their quirks an' turns—the loves an' doves they dream—
> Lord, send a man like Robbie Burns to sing the Song o' Steam!

In undertaking to do my part in the dedication of this splendid temple of science, I can but echo McAndrew's prayer, and wish that I had the words of a poet to sing the song of science. For what true devotee of science does not look upon her as a star-eyed goddess, and feel within himself at times feelings akin to those of the poet when breathing the divine afflatus? For the chief characteristic of both the poet and the scientist is the creative spirit, the poet creates beauty, or the appreciation of it, the scientist creates truth, or if he does not create truth, he at least creates the appreciation of it and of its results. I have chosen for my subject "Scientific Faith and Works." According to the Apostle Paul, "faith is the substance of things hoped for, the evidence of things not seen." In an eloquent panegyric, he recounts to us the deeds of the Hebrew patriarchs, "who by faith subdued kingdoms, wrought righteousness, obtained promises, stopped the mouths of lions,

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quenched the violence of fire, escaped the edge of the sword, out of weakness were made strong, waxed valiant in fight, turned to flight the armies of the aliens." I shall make it my task to show, by a not too literal application of the text, that similar effects may be produced through science. The more practical and prosaic Apostle James, on the other hand, in a chapter somewhat disparaging faith, exalts works, and issues the challenge, "Shew me thy faith without thy works, and I will shew thee my faith by my works." It is no doubt easier in the case of science to play the rôle of James than that of Paul. The works of science are abundant, and are appreciated of all. To catalogue them is an easy and somewhat commonplace task. But in order to better appreciate them let us take a brief glance at the world before it was under the influence of science as it is to-day.

If we consider the differences between ourselves and the ancients, we are at once struck by the fact that the chief dissimilarity is that they had little or nothing that can properly be called science. Deep thinkers they had, poets that have never been surpassed for lofty imagination and noble diction, teachers who devoted their lives to the attempt to solve the mysteries of existence, but the systematic study of the workings of nature is essentially modern. The great Hebrew nation, to whom we are indebted for so much that is fundamental in our religion and morals, brought the laws of conduct and the purity of life to an extent never equalled by the other nations of antiquity. Being essentially a race of simple shepherds and agriculturists, although in close contact with nature they produced no art, graphic or architectural, and left no engineering works to arouse our admiration for their resourcefulness. The sacred writings of the Hebrews are full of allusions to nature, in both its kind and terrible aspects. "Canst thou bind the sweet influences of the Pleiades? or loose the bands of Orion? Hast thou an arm like God? or canst thou thunder with a voice like him? Deep calleth unto deep at the noise of thy waterspouts: all thy waves and thy billows are gone over me. The heavens declare the glory of God, and the firmament sheweth his handiwork." These are specimens of the Hebrews' attitude toward nature, one of deep awe and reverence for its mighty Creator rather than of admiration for nature itself. The idea of studying into the workings of nature would, no doubt, have seemed preposterous and irreverent to such minds. The bow in the cloud was naturally accepted as a pledge made by God to men, while its circular form and unvarying arrangement of colors led to no curiosity to know why. The Egyptians, who so long were masters of the Hebrews, surpassed them in their interference with nature, and carried on engineering operations on an extensive scale, though of a simple character. They devised simple engines for raising the water of the Nile, and developed great irrigation systems, while the pyramids still

remain a source of wonder to moderns. If we may believe all that students of the pyramids tell us, the Egyptians had no mean knowledge of astronomy as well. Certain it is that the Assyrians had a knowledge not only of astronomy, but of mathematics, having highly developed systems of numeration and methods of calculation, their sexagesimal system of numeration having come down to us in the division of the circle into three hundred and sixty degrees, against which anachronism the decimal system is but now beginning to struggle. The engineering operations of the Egyptians, however, were of a very simple sort, and their construction of the pyramids was probably permitted rather by the unlimited supply of forced labor than by the employment of devices for taking advantage of anything but brute force.

As the Hebrews were specialists in morals, so the Greeks were specialists in beauty, and pushed its culture to a degree never before or since attained. Had the Greeks left to us no masterpieces of literature, we should forever remember them by their magnificent temples, their incomparable sculpture, and their beautiful vases. Such a people must inevitably have had great thoughts to express in prose and verse, and it is not surprising that they were sensible of the beauties of the intellect, and pushed the study of geometry to a very considerable extent. The value which they attached to this study may be inferred from the inscription over the door of Plato's academy, "Let none enter who is not a geometrician," a motto which, by the way, I would gladly see placed over the gate of the modern college. Archytas of Tarentum, about 400 B.C., had devised apparatus for constructing various curves, had recognized the spherical form of the earth, and its daily rotation. Aristotle wrote a voluminous treatise on animals, showing careful observation of their habits, and even left a treatment of mechanical problems in which he almost recognizes the nature of the parallelogram of motions and of centrifugal force. In the domain of physics, however, he is not particularly happy, and is better at asking questions than in solving them. A hundred years later, however, Archimedes, the greatest of the Greek scientists, not only makes great advances in geometry, including a method that is in a measure the precursor of the integral calculus, but displays an acute knowledge of the principles of statics, including the principle of the lever, and of the fundamentals of hydrostatics, especially the principle named after him. With Archimedes, as with the other Greek philosophers, the practical applications accompanied, and probably generally preceded, the theoretical inquiries, and indeed this is still usually the case. The Romans, who succeeded the Greeks in importance in the ancient world, certainly did not do so on account of their cultivation of scientific studies, in which they played a poor part. Their very clumsy system of numeration would show their lack of mathematical talent, but on the other hand their extremely prac-

tical nature led them to the execution of great engineering works, their roads, aqueducts and baths still remaining for our admiration to-day. After the fall of the Romans succeeds the long night of the dark ages, learning being kept alive only by the Saracens, and the achievements of the Greeks being so far forgotten as to require to be discovered anew. Finally came the fall of Constantinople with the dispersal in Europe of many Greek scholars, the Renaissance, and the revival of learning. Conditions were then ripe for the prosecution of all sorts of intellectual pursuits, and we find the study of nature for itself taking on a development never before dreamed of. To these the church, in many cases, did not offer a welcome. Accustomed, during the middle ages, to the supreme domination over men's minds, she did not look with favor on a movement destined to set them free from all bonds except the truth. Copernicus died too soon to come into conflict with the power of the church, but upon his follower Galileo she wreaked her vengeance, and Giordano Bruno she burned at the stake. Nevertheless, the powerful genius of Galileo gave rise to so many and so important discoveries as to constitute him the father of modern science. Not satisfied with the introspective methods of the Greeks, who often contented themselves with considering how nature ought to work, he developed the modern method of the direct appeal to nature, by means of experiment finding out how she actually did work. When in the presence of the scoffing schoolmen he dropped the heavy and the light weight from the top of the tower of Pisa, and found them both to reach the ground together, he sounded the death-knell of the old and outworn Aristotelian philosophy.

It is not my intention here to consider the history of science, and its development from the small beginnings of the cinquecento through its glorious burst in the eighteenth century to full fruition in the nineteenth. Let us briefly recapitulate some of the changes which the works of science have made in the face of the earth, and of mankind inhabiting it. First and most important is the production of power, by which man's energies are inconceivably multiplied. The discovery of coal at just the right time to be utilized in the invention of the steam engine enabled man to command hitherto undreamed of forces, making the constructions and manufactures of the ancients seem like child's play. The raising of cotton, made practical by the invention of the cotton gin, largely transformed the clothing of the world, while the development of the iron and steel industry revolutionized methods of construction. With the command of power in centralized units came the development of the industrial system, and the tendency to crowd together into cities, leading to so many scientific problems yet unsolved. With the tremendous increase in the wants of humanity brought about by the increased power to supply them, the supply of natural energy in the form of coal, which at first seemed inexhaustible,

seemed menaced, and other natural resources had to be developed, and more efficient methods of application found. Thus in our day the development of the internal combustion or gas engine, which threatens to crowd the steam engine to the wall, has finally permitted the application of petroleum, which by the aid of chemistry has furnished not only great stores of energy, but numerous useful products. Not the least important aspect of the power development is that part which is applied to transportation. The covering of the whole known world with lines of railway has made possible and easy movements from place to place not only of peoples, but of products, so that while a few centuries ago a large proportion of the population never moved more than a few miles from their birthplaces, being as good as fettered to the soil, now even the poorest may be easily displaced from country to country, the seas being no more of a barrier than the land. The increase of education by travel, and the tendency toward peace produced by the increased acquaintance of nations with each other, is not to be overestimated. Perhaps no more impressive example of man's power over nature is to be found than the sight of a great ocean steamship, lying at her dock and towering over the surrounding buildings, or ploughing her way at express speed over the stormy waves, whose power she hardly seems to feel. A notion of the huge demands made by ocean transportation on our resources of energy is obtained when we think that one of these marine monsters is using sixty or eighty thousand horsepower, while an express train uses from a thousand to fifteen hundred only. In view of this depletion of our coal supplies the question of water power has become urgent, and science has succeeded in bridling our rivers and waterfalls for further supplies, while the transmission of this power by electricity has made manufacturing possible where it was not before, and is now being applied to transportation on a large scale. Not to be neglected in connection with the application of power is the question of illumination. When we think of the dark and dismal nights in the cities, not only of antiquity, but even of two centuries ago, making it impossible to go out in safety at night, and encouraging all sorts of crimes of violence, we must consider the successive application of gas, oil and electricity to have had no mean influence on the habits of mankind. The use of modern illuminants, especially electrical, has made possible the performance of more work, under more healthful conditions, and has completely changed the habits of man as regards the hours of darkness. Whether this has been entirely for his advantage we may leave until later.

Almost equally important with transportation is communication, which has in like manner changed the possibilities and habits of mankind. At the time of our revolution it took weeks to get any news to

or from Europe, while even as late as the civil war our news was two weeks old when it reached England. What a contrast to the present, when the news of the fall of a cabinet or the overthrow of a sultan last night in any part of the world is put before us at breakfast this morning, and that not only in the centers of population, but in remote country districts. Nations can not now ignore each other's feelings and desires, while those misapprehensions which lead to war are made many times less frequent. The use of the ocean cable and of the telephone has largely transformed methods of doing business. Time is money, and although the increased facility of locomotion has led hosts of business men to circulate from one end of the country to the other, this can now in large measure be saved by the use of the telephone.

More important for the existence of man even than transportation and communication is food. The applications of science have made not one, but thousands of blades of grass grow where one grew before. Chemistry has shown how to fertilize the exhausted soil, engineering has furnished water where none was, and caused the desert to blossom as the rose. Its latest feat, in the anxiety due to the exhaustion of the nitrate beds, has been the fixation of the nitrogen of the air, which in Norway combines the harnessing of the waters with the compulsion, in the electric arc, of the nitrogen to unite with the oxygen, thus yielding unlimited nitrates for the restoration of our exhausted food supplies. Here also transportation comes in, so that the famines which formerly vexed large portions of the earth have now lost their terrors. When we think of the misery of the English agricultural classes before the abolition of the corn laws we may well praise the development of transportation which has enabled her to eat out of our full hand. At the same time the application of thermodynamics to freezing machinery has enabled us to send our meat across the ocean to become the roast beef of old England. The effects of all this upon the farmer can not be passed by. Commanding the markets of the world, ploughing his fields by steam or electricity, grinding his grain by gasoline, feeding his stock from silos, milking his cows by vacuum, cooling his cream by cold-producing machinery, separating it in a centrifugal creamer, making his cheese by the aid of chemistry so that he duplicates the product of any locality in the world, in easy reach of the city by automobile or trolley-car, and in communication with all his neighbors by telephone, he is no longer an object of derision, a hayseed, but an example of the works of science, demanding an equal part of influence in the government of the country, and gladly contributing of his rich store to the endowment of institutions like this for the education of his youth and the further advancement of science.

Again let us consider what science has done for the amelioration of health. When we consider the crowding, the filth, the misery of the

greater part of the populace in the cities of antiquity, of the middle ages, and of our own times in many cities of the orient, we can but feel that the application of science to sanitation, to sewerage, water supply, and housing, has been of immense benefit, although it has by no means kept up with the needs of civilization. The discoveries of preventive medicine have removed the terrors from small-pox and yellow fever, and made impossible the wholesale devastation of great cities by plagues which were common only a few centuries ago. In our own days we have seen the work of the microscopist reveal the cause of the most various diseases, from malaria and cholera to the hookworm disease, while the marvelous work of the surgeon's knife fills us with amazement. If it be desirable to live long, science has largely contributed to benefit mankind in this way. With the improvement in the conditions of work has come the possibility for increased amusement. Music is stored up in the phonograph, to be carried to the remotest corners of Asia and Africa, while the kinematograph has rendered all corners of the earth accessible to the multitude, and has vivified the scenes of history.

Not the least important of the works of science is its effect in the promotion of general peace. As the nations are more closely linked together by the means of transportation and communication, their interests become more nearly alike, and they do not so easily plunge into wars. The applications of science to war have at the same time made it more terrible and deadly, so that nations do not dare to expose themselves to the chance of physical or commercial extermination thereby involved. If the development of the aeroplane shall make it possible for a fast cruiser like the *Lusitania* to be sent out equipped with rapid flying-machines which, on catching the strongest battleship shall make it possible to sail over her at too great a height to be shot at, but near enough to drop high explosives that shall destroy her, war will be at an end. The late Edward Atkinson once stated that all that was necessary to end war was the invention of a gun that should pick off generals at headquarters as the Boer sharpshooters picked off the British captains and colonels.

But I have said enough in praise of the works of science. It is no doubt possible to exaggerate their praise. A most judicious and learned observer, his Excellency James Bryce, in a Phi Beta Kappa address at Harvard two years ago, has examined the question, "What is progress," and whether all our modern improvements have constituted real progress from the times of the ancients. His conclusion is somewhat disappointing, and at the end the beam inclines very slightly in the positive direction. He does consider it probable, however, that the advances of science have rendered more tolerable human life, and have lengthened its span. We must not forget, indeed, that with

nearly every new advance some disadvantage is connected, that with the development of industrialism there is connected great injustice, that the results of crowding in cities have led to great misery and sickness, problems not yet solved, and that the recent survey of Pittsburg has revealed conditions which could doubtless be paralleled elsewhere, but which cause us to blush for our boasted civilization. At the same time, these defects are not to be charged to science, but to the failure to utilize it. On the other hand the increase of insanity due to the greater strenuousness of life brought on by modern conditions is not so easily explained away.

It is not, however, for all these works of science that I wish to arouse your enthusiasm. As I have before stated, I consider James the more prosaic apostle, while it is Paul that stirs our feelings. What is the object of science, and is it worth our devotion? What are its purposes and methods, and what may we hope from it? Does it consist in building railroads and bridges, laying cables, digging tunnels and canals, and converting coal into ice? I believe it does not. Let us suppose that the advance of science, the adoption of socialism, or what not, has furnished every working man not only with three acres and a cow, but with hot and cold water, sanitary plumbing, steam heating, with cold brine for refrigeration, milk and beer laid on in pipes, with electric lighting, heating and power for the sewing machine, vacuum cleaner and the few remaining domestic necessities, with a telephone for communication and for the enjoyment of contemporary music, a phonograph and automatic piano for that of the past, an automobile and flying machine for transportation and sport, and that the hours of labor have been reduced to four, will universal happiness then reign? I fear not, if this is all. For life does not consist exclusively of eating and drinking, nor yet of pleasure. Unless what we call the soul is improved as well as the body, life is likely to be a poor thing. It is here that we come to the improvement of morals and of taste, and the need for art, literature and science. I mention these together, for their purposes are the same. They elevate the mind, kindle the imagination and give a more lofty outlook on the universe in general. It is the satisfaction of man's legitimate curiosity, his desire to know the how and the why of nature, that is, in my opinion, the true end of science. There are in the world, we are told by the late William Kingdon Clifford, three classes of persons: in the first place, scientific thinkers, secondly, persons who are engaged in work upon what are called scientific subjects, but who in general do not, and are not expected to, think about these subjects in a scientific manner, and lastly those whose work and thoughts are unscientific. Scientific thought is not determined by the subject thought of. The subject of science is the universe, its limitations those of the human mind. When the captain of

a ship finds its position by means of observations with the sextant, or when an engineer constructs a dynamo with the aid of a drawing and data known to be correct, he does not engage in scientific thought, although he makes use of experience previously collected. When the computer in the office of the Nautical Almanac computes an eclipse of the moon, foretelling it to a second of time several years before the event, he is not engaged in scientific thought, but is making use of technical skill. When, on the other hand, Adams and Leverrier, computing the positions of the planet Uranus, found them not verified in fact, but by the assumption of a new hypothesis, were able to discover the planet Neptune, they were engaged in scientific thought of a high order. The collection of facts, as one collects postage stamps or coins, does not constitute science. In order to have science the facts must be fitted into a definite system, in accordance with a classification on the basis of what we call laws. It is a prerequisite for the existence of any science whatever that we admit that nature is subject to uniformity, that is, that similar circumstances of similar things will be followed by similar results. The belief that the order of nature is reasonable, that is, that there is a correspondence between her ways and our thoughts, and that this correspondence can be found out, is what I have called scientific faith. The method of the inductive sciences, those that concern the facts of nature, is first to observe a class of seemingly related facts in order to find out what they have in common, then if possible to form some hypothesis as to their relation, then to compare the different cases with the hypothesis in order to see whether it is justified. When this process has been successfully carried out, we are able to predict what will occur in given circumstances, although these circumstances have not occurred. This is what we mean by discovering a law of nature, namely, finding a common property of a class of phenomena, such that under all circumstances the phenomena which will ensue can be described. This is what constitutes the difference between scientific and technical thought. Technical knowledge enables us to deal with cases that have occurred before, while scientific knowledge enables us to deal with what has not occurred before.

This is a matter that is not always understood in this country. It is a matter of common knowledge that this country stands very high in technical knowledge, but it is not so often pointed out that her contribution to science has as yet been distressingly small. Numerous examples might be given. We have just been celebrating the anniversary of Fulton's steamboat, with well-deserved enthusiasm. Nevertheless we must remember that Fulton did not invent the steamboat, nor did he construct the first one. He combined knowledge then existing with practical sense and business acumen, and was able to build a

boat so large and successful as to convince the world of a new mode of transportation. In recent times the question of developing the power of Niagara involved the construction of turbines larger than had ever been built. These were built in Philadelphia, by means of the technical skill there existing, but the designs were made in Geneva by the well known engineers Faesch and Piccard. As a matter of fact the Swiss had long since developed the theory of the turbine, and were prepared to design one of any size on the principles already found sound. More recently the steam turbine has come into the field formerly the exclusive possession of the reciprocating steam engine. Curiously, the first successful turbines came from England, then a large number were developed in Germany and France, while at the present time we have one very successful American turbine. Now the physical principles involved in the turbine are quite different from those of the reciprocating engine, and involve considerable theoretical knowledge of the properties of fluids in rapid motion, some of which were familiar in the case of water, but which were of a different sort for an expansive vapor like steam. It is very noticeable that the best treatises on the steam turbine to-day are German, and begin with a large amount of theory on the properties of rotating discs, then of the thermodynamics of vapors, and finally of the flow of steam through jets, before the technical matters are touched. We are now hoping for the development of the gas-turbine, which shall combine the two advantages of the gas-engine and the turbine, and which will demand for its success all the knowledge of thermodynamics which we possess. As a final example take the case of wireless telegraphy. This country was a pioneer in ordinary telegraphy, having not only Morse to contribute the technical knowledge, but before him Henry with his scientific development of the electromagnet, but the wireless telegraph was imported in an advanced state of development, from England, where the scientific acumen of Maxwell had predicted the action of the electric waves. I am sorry to say that I feel that there is a tendency among our engineers or at least among our engineering students to try to do their work with a very small amount of scientific thinking, and it seems to me that this tendency must be overcome if we wish to maintain a successful competition in either science or technology with such a thorough-going scientific nation as Germany.

There is a tendency to-day in some quarters to disparage the use of hypotheses. With this tendency I do not sympathize. It is difficult to see how scientific advances can be made without the use of hypotheses, nor has that been the ordinary custom. The phrase of Newton has been quoted, "*Hypotheses non fingo,*" but certainly that must be interpreted as meaning that he did not form unnecessary explanations of phenomena rather than that he did not proceed by means of working

hypotheses, for he did. By making the hypothesis that the earth attracted bodies according to the inverse square of the distance, and calculating whether the fall of the moon toward the earth was of the amount required by this supposition, he was able to predicate the law of gravitation, and by the calculation that the orbit of a body attracted according to this law would be an ellipse he was able to explain the law of planetary motion discovered by Kepler. It is difficult to see how Kepler could have arrived at his law of elliptic motion if he had not first guessed that the orbits of the planets were circles or conic sections, and then verified it by comparison with the observations on their apparent positions.

The chief test of the success of a scientific hypothesis and of a train of reasoning therefrom is found in the ability to make predictions. Of this probably the most striking example in all science is the law of gravitation just alluded to. All the observations of the last two hundred years have only resulted in confirming Newton's conclusion, while the accuracy of astronomical prediction exceeds that of any part of science. Such is an example of scientific faith. Another famous example is Hamilton's famous discovery of conical refraction. On looking through a piece of Iceland spar at an object one sees it doubled. The laws of this double refraction had been thoroughly described by Fresnel, who related them to a certain geometrical surface invented by him. By the study of the geometry of this surface, which was found to possess two singular points, Hamilton showed that on looking through the crystal in a certain direction at a point, one would see not two points but a whole continuous circle. This experiment was made by Hamilton's friend Lloyd, who saw the circle, confirming in the most brilliant manner the wonderful imagination of Hamilton, who saw in his mind's eye what never yet man had seen.

Another example of successful hypothesis is afforded by the kinetic theory of gases, which explains the properties of gases by the hypothesis that they consist of extremely small particles in very rapid motion, which by striking each other and the walls of the containing vessel by the impacts give rise to the pressure which the gas exerts. On this theory the friction which a current of gas exerts on a portion moving less rapidly, thereby setting it in motion, is of the same nature as the action that a crowd of men jumping from a moving train to a car upon a parallel track would have, their momentum tending to set the second car on which they alighted in motion. One of the remarkable predictions of this theory is the result of Maxwell that the viscosity of the gas is independent of its density, a result which has been well verified by experiment.

As a final example of scientific thought, let me briefly refer to the hypothesis of the luminiferous ether. About one hundred years ago,

this hypothesis, that light consisted of a motion of the nature of waves, obtained the victory over the old notion that light consisted of small particles shot out from the luminous object with great rapidity. The laws of the propagation of these waves were thoroughly described by Fresnel, but what the properties of the substance in which they were propagated, and called the ether, might be, was long a matter of difficulty. Green had shown that an elastic solid of a certain sort would possess many of the properties of the ether, but this mechanical theory was insufficient in certain ways. It was the conjecture of Faraday that the actions of electrified and magnetic bodies upon each other, so thoroughly investigated by him, were transmitted to each other by means of the ether, and it was the genius of Maxwell and his wonderful scientific imagination, that enabled him to erect this conjecture into a remarkably perfect theory. By means of the hypothesis that electrical and magnetic actions are subject to the laws of mechanics, Maxwell was able to apply to electric currents the equations of Lagrange for dealing with the motion of the most general mechanical systems of bodies. In this way Maxwell explained the laws of the induction of currents, the difficulty of starting or stopping a current corresponding to the inertia of a heavy body. Presently by the aid of an auxiliary assumption the properties of the ether were described, and the remarkable result found that electrical and magnetic effects would be propagated with the velocity of light. From this it was a short step to declare light waves to be electromagnetic waves. Such waves were not known at the time of Maxwell's paper in 1865, and his theory waited long for acceptance. In 1888, however, Heinrich Hertz, guided by his great master Helmholtz into acceptance of Maxwell's theory, succeeded, in a most brilliant series of experiments, in producing the very waves predicted by Maxwell, and in showing that they traveled with the velocity of light. These are the waves made use of by Marconi for transmitting intelligence, and conquering the sea in peace and in war. But this is not all, for Maxwell, in his description of the manner in which the ether transmitted the electromagnetic waves, assumed that it was subject to certain stresses, so that a surface receiving a beam of light would experience a certain pressure, the amount of which he calculated. This result awaited verification until 1900, when the Russian physicist Lebedew, and in 1903 still more exactly the Americans Nichols and Hull, now president and professor, respectively, at Dartmouth College, gave it a magnificent verification. Thus by faith Maxwell subdued kingdoms, obtained promises, out of weakness was made strong, turned to flight the armies of the aliens of ignorance.

An interesting conclusion that may be drawn from the history of scientific endeavor is that there is an accepted time for each discovery, that is, that a certain stage of human progress the discovery is cer-

tain to be made, independently of the existence of any particular investigator. Such a truth is apt to put the scientist in that humble mood characteristic of the true man of science, and to show him how unimportant in the scheme of nature is any particular individual, but it need not leave him in the state described in the hymn, "Great God, how infinite art Thou, what worthless worms are we!" Examples of this conclusion are numerous. The discovery of Neptune simultaneously by Adams and Leverrier has already been mentioned. Singularly enough the planet was seen first by Galle, at Berlin, on September 23, 1846, and then independently by Professor Challis, at Cambridge, on September 29, he being ignorant of Galle's discovery. The statement of the Second Law of Thermodynamics in 1850 by Clausius and Lord Kelvin, and the discovery that the specific heat of saturated vapor is negative by Clausius and Rankine and others. The published work of Sir Oliver Lodge on electric waves shows that it admits of no doubt that had not Hertz published his researches when he did Lodge would have obtained many of his results. The work of Helmholtz and Lord Kelvin is full of interesting parallelisms, while the important application by Helmholtz of thermodynamics to chemical phenomena was anticipated by our own Willard Gibbs. Coming down to the present time, it is no disparagement to Wilbur and Orville Wright to say that had they not succeeded in the conquest of the air the same result would shortly have been achieved by Blériot, Voisin and others. I have no doubt that, had not Columbus discovered America in 1492, some other intrepid navigator would have done so in ten years. Had not Peary discovered the pole—but I pause, as fiction is sometimes stranger than truth.

I will now, with your permission, undertake to make a rough classification of the sciences, and make some remarks on the differences in their methods. Sitting serene at the head as queen of all is mathematics. Ready she is to serve all, and what a servant she can be is witnessed by those other sciences that have most need of her. Mathematics is probably the most misunderstood of all the sciences. Huxley called it "that science which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation." To this a sufficient answer might be that she does not need to, but a better one is that it is not true. Intuition and induction have a great part in all mathematical discoveries, as all of the great mathematicians agree. Mathematics has no subject matter, but may be applied to anything that has exact relations. To sing the beauties of mathematics to those ignorant of that subject is as futile as to praise music to the tone-deaf, or painting to the color-blind. I have a friend who describes a symphony as a horrid noise. The president of a great eastern university has said that the manipulation of mathematical symbols is a mark

of no particular intellectual eminence. Presumably he had never tried it. To the often-repeated charge that mathematics will turn out only what is put in we may reply that while from incorrect assumptions it can not get correct results it has the power of so transforming the data as to reveal to us totally unexpected truths. Witness the magnificent generalizations of Adams and Leverrier, of Hamilton, and of Maxwell already quoted. There is no doubt that the invention of the infinitesimal calculus has furnished man with the most powerful and elegant instrument of thought ever devised. Allow me to try in a few words to tell why this is so. Natural phenomena are not, as a rule, discrete, like integral numbers, but continuous, like points on a line, so that there is no least difference between one and another. We say that they are continuous, and that they vary continuously. The examination of continuous change is the function of the differential calculus. When we undertake to define so simple a matter as the speed of a point, we can not say that the velocity is the distance traversed in a given time, unless during the whole of that time the speed is the same. If it is continually changing we must divide the time into less and less intervals, and find the ratio of the distance to the time required when both become smaller than any quantity conceivable, in other words we must find the *limit* approached by this ratio. Thus all questions relating to rates of change, to slopes of curves, to curvature, and the like, require the method of limits, as applied in the differential calculus. On the other hand, consider the case of two bodies attracting each other according to any law of the distance. Since the body is more than a point, from what point of the body shall the distance be measured. Obviously each small portion of the body contributes its part in the attraction, with a different amount according to where it is, all these amounts requiring to be added together to make the whole. But how many parts shall there be, and how large. Obviously there is no bound to the number, nor to the size, one increasing as the other decreases. We must accordingly take the limit which this sum of all the actions approaches as we increase the number of parts while diminishing their size below any limit whatever. This is the method of the integral calculus, Now as observation enables us to deal with bodies of finite size only, the inference to the laws of the ultimate parts can be made only deductively by the calculus. In practise, however, the inverse process is more frequently employed, that is, the actions of points infinitely near each other in space, time or other circumstances are assumed to follow some simple law, thus giving us what are called differential equations, the integration of which gives us conclusions as to what happens on the large scale, which conclusions can be compared with experiment. It is on account of the logical importance of the method, the universality of its applica-

bility, and the intellectual power developed, that I could wish that as a counterpart to Plato's motto should be placed over every college gateway, "Let none depart hence who knows not the calculus," at least as to what it deals with, and its fundamental principles.

I am glad to say that in some of our colleges are now given courses in what is termed "culture calculus." It seems to me that this subject is more deserving of the name of culture than the familiarity with the immoralities of the Greek gods.

Of the natural sciences there are two fundamental ones, physics and biology. Physics has to do with all the universe, in so far as it possesses energy, and exerts forces one part upon another, and in so far as it does not possess life. Biology deals with all matter possessing this difficultly defined attribute, but so far as we know, even the phenomena of living matter are subject to the laws of physics. I presume that every biologist will admit that life does not create energy, but merely directs it. Nevertheless, the question of vitality is to-day far beyond the explanation of the physicist. The subdivisions of physics have been, for convenience only, set off as individual sciences, chiefly because the whole subject would be too large for the treatment of any individual scientist. The most important part of physics is dynamics, which treats of the laws of motion, and the forces which are associated therewith. Of this a great division is celestial mechanics, which, as we have seen in the cases of Galileo and Newton, contributed in great part to the inductive establishment of the laws of motion in general. The remainder of astronomy is now catalogued as astrophysics and is dealt with by purely physical methods and instruments. As a subdivision of astronomy may be reckoned geodesy, which deals with the form of the earth, deduced from astronomical measurements and from its gravitational attraction.

Chemistry is that part of physics which deals with the properties of substances that have individual characteristics by which they may be always distinguished, and which combine with each other in definite proportions. Its methods are those of physics, its main instrument is the physical balance, and it is in recent years concentrating more attention upon those physical relations connected with temperature, pressure, and electrical relations, all of which are now found to yield to mathematical treatment in a manner until recently unsuspected.

The methods of physics and chemistry usually involve the controlling of certain of the circumstances under which phenomena occur, so that the changes in others may be more easily observed. This is usually done in a laboratory furnished with many means of controlling circumstances, for instance, temperature, pressure, electrical or magnetic state, so that the same circumstances may be reproduced again and again. Meteorology, or as it is now somewhat grandiloquently called, cosmical

physics, has to do with those phenomena of the atmosphere, the ocean, or the magnetic state of the earth, which are not controllable by man, and which can not, therefore, be repeated at pleasure in the laboratory, but must be observed when and where they occur. The same applies to geology, which is the application of physics, chemistry and even biology, or any science whatever, to the earth, in relation to its physical constitution and its history. Geography deals with the face of the earth, and uses the results of geology to study the earth as fit to be the dwelling place for man. There remain the technical applications of physics in all kinds of engineering, civil, mechanical, electrical, chemical or mining, involving the strength of materials, elasticity and the direction of the natural sources of energy to the purposes of man. All these applications of physics need, and are highly susceptible to, mathematical treatment, and for that reason they are the most perfectly developed of all the sciences.

Let us now turn to the biological sciences. The two fundamental divisions, zoology and botany, dealing with animals and plants, seem to run continuously one into the other, like chemistry and physics. Under both we have the subdivisions of morphology for the study of form and physiology for function. Under zoology we put anatomy, and the various more specialized sciences which find their technical application in medicine. There still remain anthropology, the study of man and his practises, psychology, which deals with the workings of what we call his mind, or that of animals, sociology, properly a part of anthropology, dealing with man when living with his fellows, and economics striving to teach him how to get along with them still better.

This classification is admittedly rough, but it does not separate closely connected things as some that I have seen do. For those who desire finer splitting I refer to the classification of the Scientific Congresses of St. Louis in 1904. Of these biological sciences the methods are somewhat different, they are mostly still in the descriptive stage, and have rarely attained sufficient quantitative information to be capable of mathematical treatment. And yet that must be their ultimate object, for without mathematics there is no exact description. That this is not impossible even in biology may be seen from the following example. If a bacterial culture be inoculated into a jelly with the point of a needle, it will be seen under the microscope to grow in all directions from the original center, and if pains are taken to ensure the physical homogeneity of the jelly the shape of the colony will be an almost perfect circle. If the diameter of this circle be measured at regular intervals, I have no doubt that a quantitative law of growth can be deduced, and even a differential equation found, which will turn out to resemble that of certain physical phenomena, say the conduction of heat. We may observe that the instruments and methods of the physi-

ologist and the experimental psychologist are already largely physical, and their researches are carried on in laboratories. In proportion as the various circumstances are rendered more amenable to external control, so the methods of biology will more nearly approach those of physics. Whereas biology was until recently chiefly a science of observation, it has now become in a high degree experimental. The physiologist removes or alters organs, removes eggs from the natural parent and places them in a foster-mother, cuts off the heads and tails of worms and observes the conditions of survival and regeneration. If the force of gravity were removed, in what direction would a plant grow? If an egg be subjected to centrifugal force in which direction will the head of the animal appear? These are the sort of questions that the biologist is now attacking. Nor is he without mathematical statements. The great generalization of Darwin of fifty years ago has ever since concentrated attention on problems of development and heredity. Darwin's conclusions were the results of the observations of a long life. Now the experimental method enables one to hasten and accelerate conclusions. The gentle monk and acute man of science, Gregor Mendel, forty years ago in his cloister at Brünn by his careful experiments on the crossing of thousands of peas, and by comparisons of their seeds, flowers and stems, succeeded in unveiling a law which has profoundly influenced ideas on heredity, not only in plants but in animals. He finds that in the process of hybridization there are certain characteristics which are transmitted entire to the offspring, and are termed dominant, others which seem to disappear or become latent in the process, which he terms recessive. When however the hybrids are bred together both qualities reappear in the offspring, and in a definite proportion of three of the dominant to one of the recessive. In the next generation another definite proportion occurs, and so on. We here have a very definite arithmetical relation, which is susceptible of very exact study and confirmation.

The method of Mendel, which we may call that of experimental evolution, is now of wide application, and there are laboratories which do nothing else but breed and cross under very exact control. Among one of the large-scale experimenters in this line may be mentioned Mr. Luther Burbank, who, though a master of method and subsidized by the Carnegie Institution, seems to be devoted rather to practical than to scientific results.

In connection with the laboratory or experimental method in evolution, must be mentioned a most promising application of mathematics to biology in the new science of biometrics, or the application of the methods of probability or statistics to great numbers of similar objects. If the doctrines of evolution or of variation are ever to be accurately proved it must be in this manner. To illustrate, suppose we have a

phenomenon in which chance is involved, and that two events are equally likely, such as throwing head or tail with a coin. Suppose we have a vertical board in which are stuck horizontal pegs in a regular arrangement of rows and columns. Suppose a shot be dropped over the middle of this array of pegs, and assume that if it strikes a peg it is equally likely to drop to the right or the left. The next time it strikes a peg the chances are the same. It is obviously very unlikely that a shot will continually fall on the same side, while the likeliest thing that can happen is that it shall fall in the middle. Hence if a large number of shot are let fall they will be found, if caught where they fall, to be arranged in a form limited by a curve highest in the middle, and gradually falling symmetrically toward both sides, known as the curve of errors. This curve represents graphically the result of an infinite number of causes acting, each as likely to produce a certain effect as its opposite. Let us now take some biological subject of investigation, say the length of a certain kind of shell. Many thousands being measured, it is found that they vary from the average, but in such a way that very few differ very far from the mean. If the number having any given length is plotted vertically corresponding to the deviation from the mean laid off horizontally, we shall obtain a curve which will generally closely resemble the curve of errors. If this is the case we shall conclude that the causes of the variations in length are perfectly at random, but if we find that the curve is unsymmetrical, or for instance has two summits, we shall know that at least two sorts of causes are acting. Thus questions of heredity and variation may be mathematically studied. This method has been greatly developed by the mathematician, Karl Pearson, who has now devoted himself to the study of evolution by mathematical means.

Finally, that apparently most remote of the sciences from the exactness of physical laws, economics, has been brought under the treatment of mathematics, not only by statistical methods like those just described, but by methods of the calculus. The distinguished mathematician and economist Cournot applied to the theory of wealth methods like those used in mechanics to treat of equilibria, so that very complicated economic principles were amenable to treatment by symbols.

I have, I think, said enough to show the power of science to transform the world, and to develop the mind of man. Is not this development of high spiritual value, and is not the pursuit of truth irrespective of prejudice and authority a noble object, worthy of the devotion of a lifetime? Of the moral values of science it would be easy to give arguments. One has but to consider the self sacrifice of many of its devotees, who consider neither toil nor time if only the good of the race be advanced. Galileo was tortured, Giordano Bruno was burned, and to-day the daily papers bring us news of lives lost in

the study of the cholera, of the plague, of the sleeping sickness. The spirit of science is well illustrated by the gift to the Pasteur Institute by M. Osiris last summer of thirty millions of francs. He was led to do this by the fact that the director, Doctor Roux, having won a prize of one hundred thousand francs for the discovery of a diphtheria serum, though not a rich man, immediately turned it over to the institute. Feeling that a cause capable of producing such unselfishness must deserve support, M. Osiris made it this large bequest. Lord Rayleigh, in like manner, donated his Nobel prize of forty thousand dollars to the physical laboratory at Cambridge.

In closing, permit me to recommend the scientific career to young men as one of great satisfaction, whether one succeeds in it or not. To be even a soldier in this noble army, to feel oneself the follower of Faraday, of Helmholtz and of Maxwell, to push on the standard of truth, is worth more than to dress in purple and fine linen and to own many automobiles. There are in this country of eighty millions only about five thousand scientists. The country needs you, young men; it is a patriotic duty to put her where she should stand intellectually among the nations. Would that I might reach the rich, and sing to them the praises of this sort of service. In other lands the rich serve the state, why not here? Surpass your less fortunate brothers not in your pleasures, but in your achievements. And then the American college will be exempt from some of the criticism that it meets to-day. Finally let us bear in mind that while we admire the palaces of science like this, they are not necessary for the performance of good work, and that those of us who are obliged to work in less sumptuous abodes may be consoled with the reflection that most of the great discoveries in science were made with simple apparatus, in humble quarters, but by great men. It is the *spirit* that quickeneth. For the true scientific spirit may we ever pray, for the works of the Lord are great, sought out of all them that have pleasure therein.

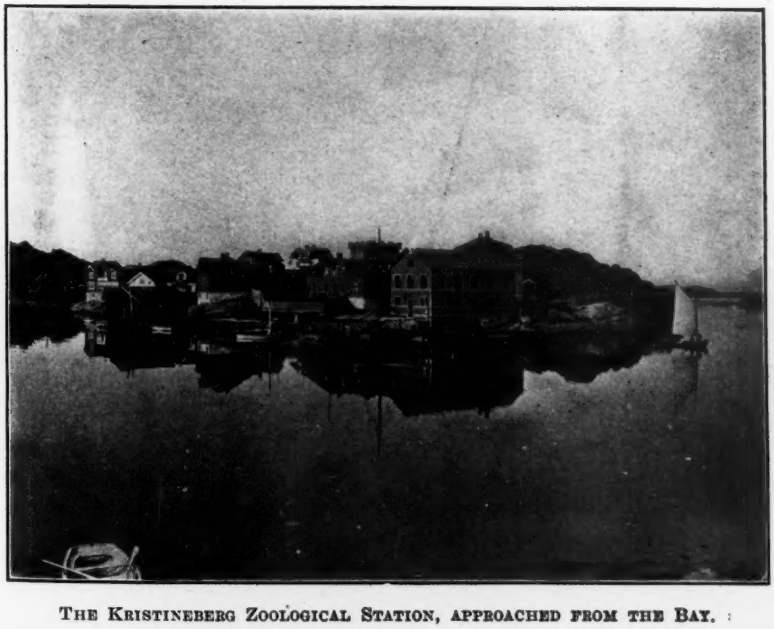
FROM AN OIL PAINTING BY FRU GULLSTRAND.

THE SWEDISH KRISTINEBERG MARINE ZOOLOGICAL STATION

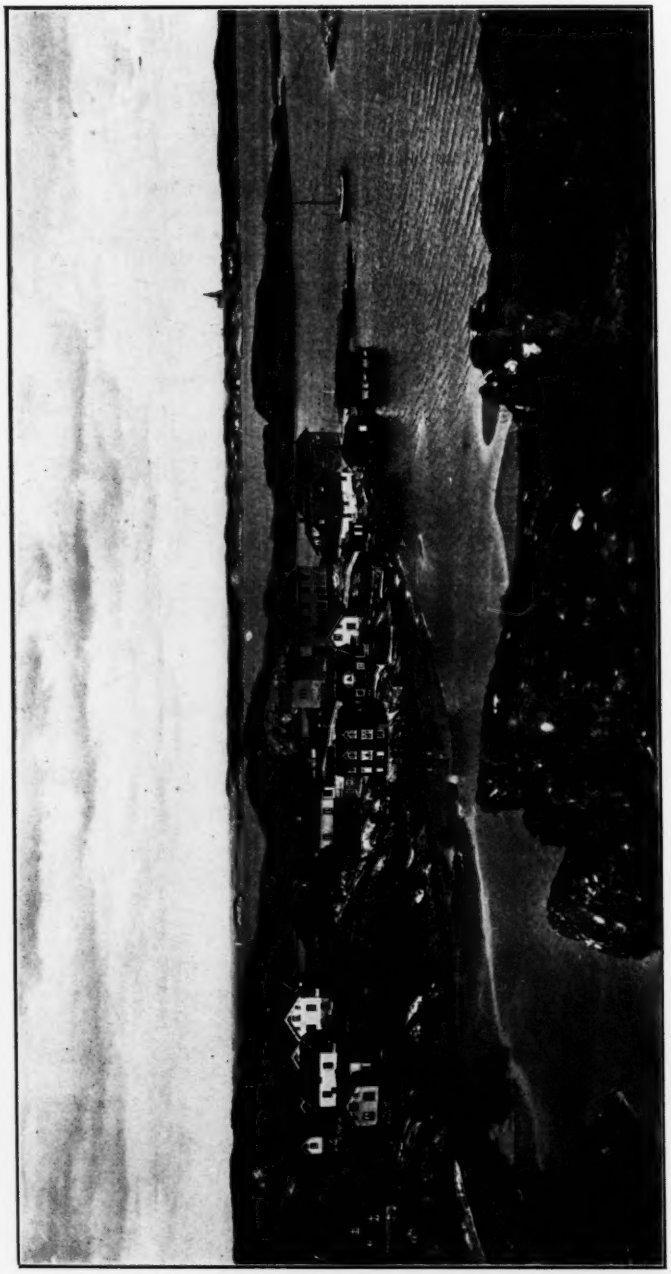
By Professor CHARLES LINCOLN EDWARDS
TRINITY COLLEGE

NESTLED among the outcropping granite ledges and islands of the west coast of Sweden, lies the village of Fiskebäckskil, near which on Skaftö has arisen the Kristineberg Marine Zoological Station. The primordial mass of the surrounding rocks and hills was planed off in curved and deeply-scratched surfaces by the vast ice-sheet of the glacial epoch. From the crests of the hills one can see the blue waters of Gullmar fjord penetrating inland and, off to the west, beyond Gasö, Flatholm and others of the protecting archipelago of islets, the white capped waves of the Kattegat.

Lichens and mosses partly incrust the rocks, and from every soil-collecting crevice, grass and wild flowers give life to the hills near at hand, while at some distance the great rocks seem bleak and desolate. In these patches of wild flowers the colors are brilliant, pink heather contrasting with blue-bells and golden hökfibla. Beside the pools of

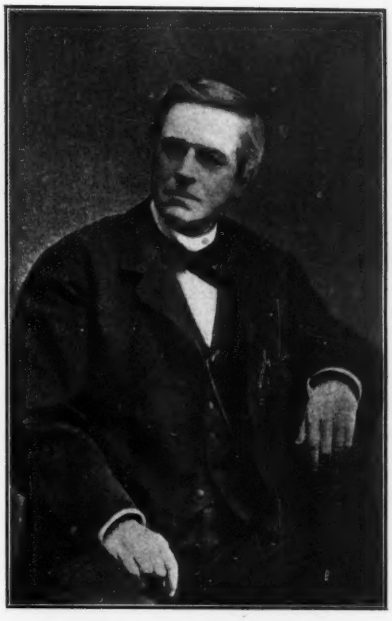


THE KRISTINEBERG ZOOLOGICAL STATION, APPROACHED FROM THE BAY.



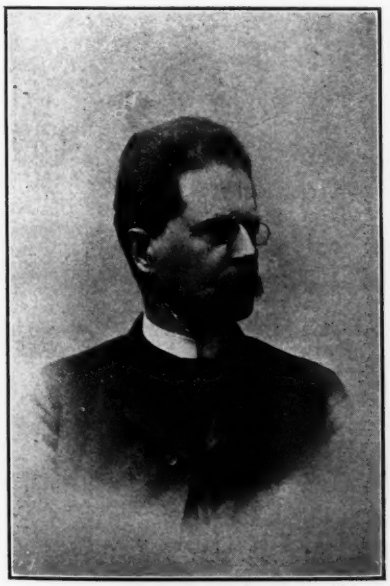
THE KRISTINEBERG ZOOLOGICAL STATION, AS SEEN FROM THE CLIFFS.

rainwater the white, downy "field-wool" waves from dried stems, and from the more shaded niches in the granite arise the graceful fronds of ferns. The large black-hooded gray crow flies from hill to hill, while on the ground the pert gray backed white wagtail nods its head and flirts its white bordered tail.



S. LOVÉN.

It was near the end of the eighteenth century when the Danish zoologist, O. F. Müller, made the first trawl in a form still in use for the collection of animals living upon the sea-bottom, and thus began the special study of marine zoology. Fiskebäckskil was visited for zoological research by Professor Bengt Fries in 1835. Four years later Sven Lovén and others joined the colony of naturalists, who worked with such meager facilities as the place could offer. Around the islands in the bays and fjords of the region they found a rich and interesting fauna distributed from the shallow flats to depths of eighty fathoms, over bottom varying from rock, sand, shell, clay and ooze, to a carpet of grass and algæ. The foundation here of the Kristineberg Zoological Station by the Royal Academy of Science in 1877 was due to the initiative of Lovén, who had become the most famous and influential Swedish zoologist of the nineteenth century. For almost sixty years Lovén investigated problems in the morphology, comparative anatomy, embryology and taxonomy of various classes of invertebrates, especially of the echinoids, or sea-urchins. He had been a pioneer in Swedish Arctic scientific expeditions and deep-sea exploration, and hence it was fitting that he should suggest the creation



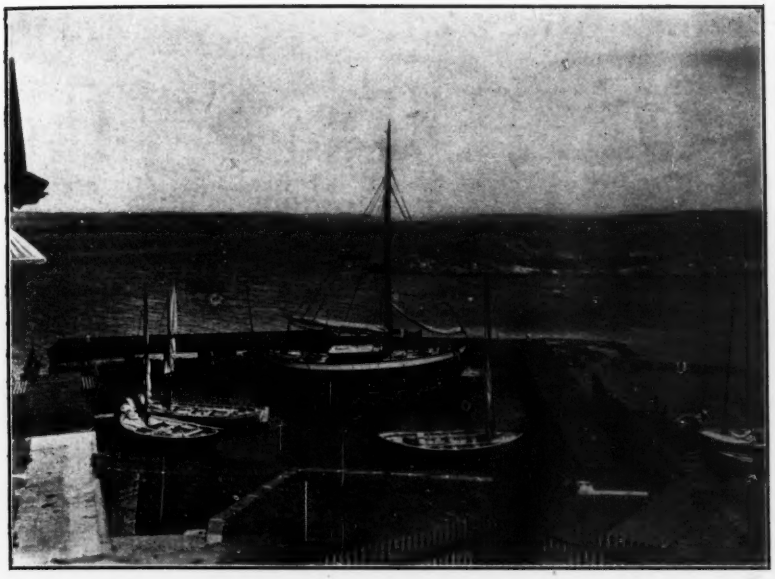
HJALMAR THÉEL.

of this station in the region where so much work of value had already been accomplished. It was not possible to have a good marine station nearer Stockholm on the east coast because the waters of the Baltic in former times was a vast lake and now receiving the outflow of many rivers, has a comparatively small percentage of salt, and consequently its fauna is poor in marine species. The physician A. Regnell gave the necessary funds to primarily establish the Kristineberg station.

In 1892 Lovén's friend and biographer, Professor Hjalmar Théel, succeeded the founder as director and to him is due the reorganization and enlargement of the station now not only open during the summer for university students and public school teachers, but also all the year

A Winter View of the Kristineberg Zoological Station.

for the investigating naturalists. Many animals which in the summer live in the depths in winter come up into the littoral belt, where their life-history can be studied to the best advantage. Almost nothing is known of the fate of the littoral fauna of the shallow bays when in winter the sand and slime in which these animals live is often frozen solid. Professor Théel's experiment demonstrated that a frozen mass of barnacles will not only resist —18° Centigrade, but revive after the ice melts and leave many young. For the solution of such physiological problems it is necessary to have the station available in winter as well as in summer. This was made possible in 1901 by a gift of 40,000 crowns from Konsul Broms, Mæcenas of the Swedish expedition to Spitzenbergen and eastern Greenland. The funds were used to the



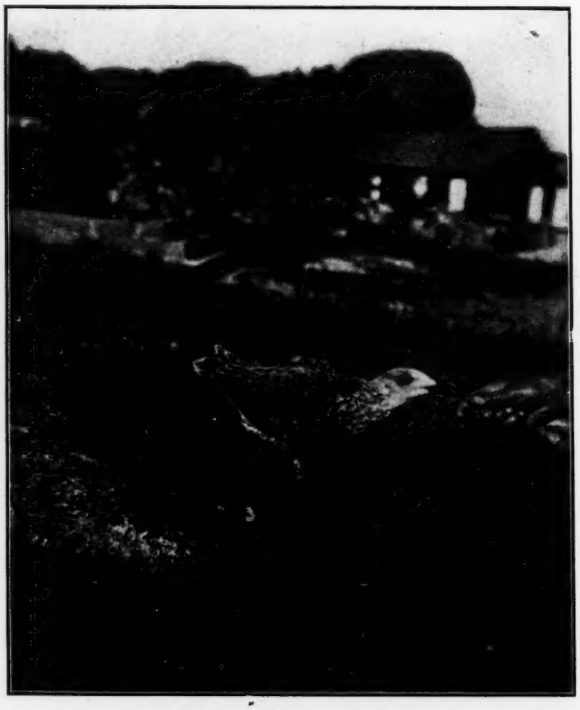
THE SAILBOATS AND THE MOTOR SLOOP "SVEN LOVÉN" IN THE HARBOR.

best advantage, so that now the station has a very substantial granite building in addition to the old laboratory erected in 1884. There are also three residences, a water tower reservoir and smaller houses for pumping salt-water and generating acetylene gas. A motor sloop of ten tons, the *Sven Lovén,* completely fitted with winding-reel, and the various patterns of trawls and dredges, as well as an enlarged granite wharf, were the gifts of Fru Anna Broms. A complete collection of well-preserved specimens illustrates the marine fauna and enables the stranger to readily identify any of the animals he may find. In a sunny room where the busts of Charles Darwin and Sven Lovén face one another, is a working library of 4,500 zoological journals, monographs and shorter papers mainly presented by Professors Théel and Retzius. Any writings not at hand can be supplied from the library in Stockholm within a few days. The station has an annual income of 10,000 crowns, 6,000 from the Royal Academy of Science and 4,000 from the Swedish government.

The grounds are fenced from the summer visitors of the neighboring Fiskebäckskil and the more fashionable Lysekil on the other side of the entrance to Gullmar fjord. The rules, firmly but courteosly enforced, establish an atmosphere of quiet. Investigators and students are provided with the animals desired, as well as all of the necessary apparatus and chemical reagents, and every assistance is most generously extended. Besides the *Sven Lovén* a fleet of sail and row boats is equipped and ready for the work of collecting, or for the observation of the animals in their own environment. The very slight tide makes

the sea here almost like an inland lake, and gives none of the many tide-pools which constitute such an important part of the collecting grounds in our American stations.

In the two laboratories there are many large and small aquaria, with such an abundant supply of sea-water that animals from a good sized shark to the most delicate coral polyp will live in contentment. The frontispiece from a painting by Fru Astrid Gullstrand represents a corner of one aquarium. The orange colored anemone, like a veritable flower, unfolds its stinging tentacles to entrap the unwary minute animals swimming by, while below, the eleven-rayed sun-star pulls itself by the contraction of hundreds of adhering sucking tube-feet. With sharp pincers the spider-crab has broken off pieces of algæ and hydroid colonies and then planted them among the bristles on its back. Thus the creature is completely masked both from the game it hunts and its own carnivorous foes. The edible mussel spins strong threads from its byssus gland firmly attaching the bluish, or sometimes brownish, shell to the rock or to another mussel. Protectively colored by the olive-green alga around the stem of which his prehensile tail is entwined, *Nerophis,* the needle-fish, as a model father, broods his young, which are glued fast to his ventral surface during development.



THE LABORATORY PET.

The station is primarily under the direction of Professor Théel as Prefect, while director Dr. Hjalmar Östergren is the very efficient administrator of affairs. Under such leadership one may feel confident that the dream of Lovén and Théel will be fulfilled and that here in Kristineberg, as at Naples, will evolve a great station, not alone for work in marine zoology but as well for the investigation of allied problems in botany, chemistry, hydrography and meteorology. Thus Kristineberg is a link in the chain of the more than fifty world encircling marine biological stations. Here and in Bergen, Kiel, Plymouth, Roscoff, Banyuls-sur-Mer, Villefrance, Trieste, Naples, Batavia, Misaki, San Diego, Pacific Grove, Cold Spring Harbor, Woods Holl, and the other sea-side stations, as well as upon the vessels designed as floating laboratories, investigators are solving the mysteries of life in the sea, the primæval birth-place of life itself.

A Group of Investigators and Students.

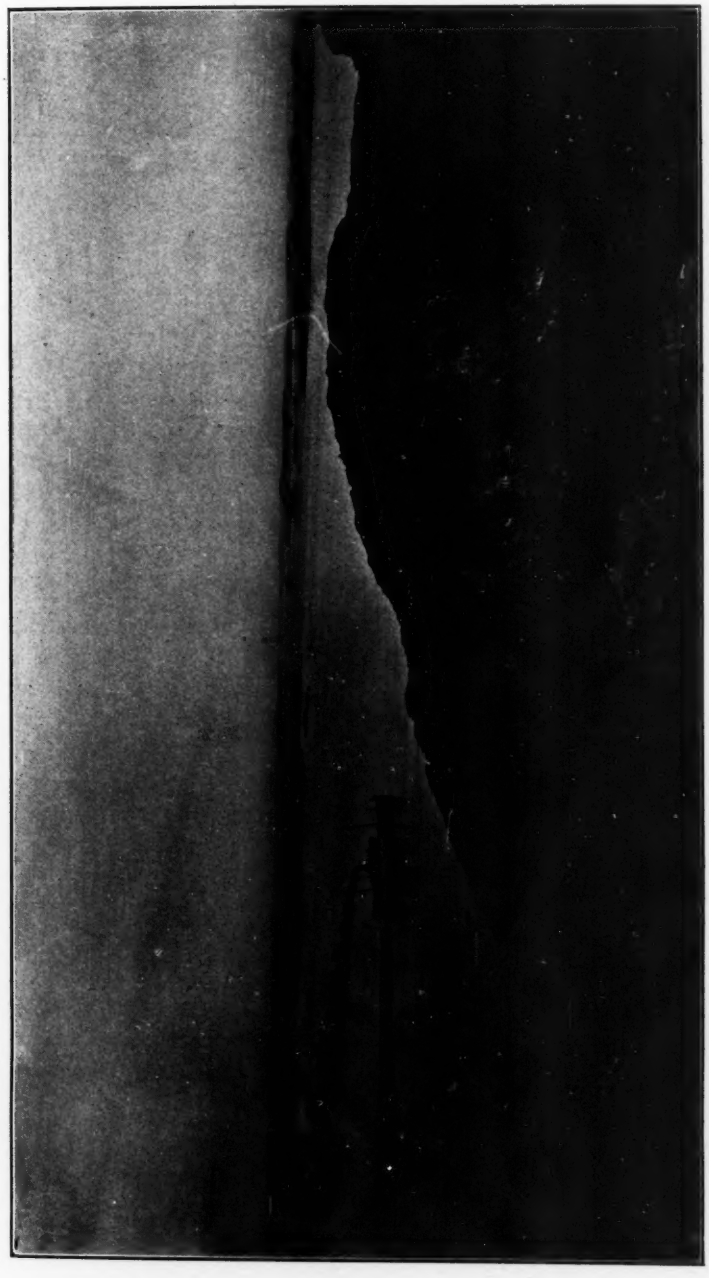
One is reminded that it is the land of the midnight sun by the twilight lasting until after ten o'clock and the break of dawn at three, when the gulls awaken us with a chorus of hoarse cries like those of migrating geese. One of their number is the laboratory pet. It was taken, as Director Östergren naïvely remarked, "When the parting from its parents was without pain," and reared with no fear of man. It is of adult size and strong enough to fly over land or water wherever it pleases. When hungry, and that is most of the time, it sounds a shrill whistle, throwing its head up and down, until a fish is offered, when it comes to one's hand to be fed. But gradually the racial instinct has been asserted until, at the last, the gull follows the call of the wild

so much of the time that little is seen of it within the laboratory precincts.

By seven o'clock the engine of the *Sven Lovén* is warning us by a series of sharp explosions, accompanied by a cloud of dark smoke and fumes from the burning crude oil, that everything is in readiness for a collecting trip. We scramble aboard and Albert Henriksson, the capable draggmästaren, swings the tiller around so that we head up Gullmar Fjord.

In the distance the hills rise from the water like banks of purple mist while the nearer rocks are as clean cut as cameos. In an hour we come to the deeper waters where under fifty fathoms the beautiful red holothurians browse. Our object is to study the embryology of these cousins of the star-fish and we get them with a trawl built like the front half of an old fashioned bob-sled from which a long hood of netting runs out behind. In a half hour the engine gear is shifted and the piano-wire cable carrying the trawl is wound in. With rope and tackle we lift the great mass of slimy ooze and organisms on deck, pick out our holothurians, place them in a weighted box and again lower them to the bottom, in the hope that eggs will be laid and fertilized for our work on the unknown life-history of this species.

Again by means of the fine meshed plankton net we seek some ctenophores and in a short time a number of these exquisite ovoid jelly-fishes are found in the glass collecting-jar at the blind end of the net. Each bilaterally symmetrical body, transparent as crystal, is propelled by eight meridional rows of minute paddles, which shimmer in the sunshine like rainbows. At the upper end of the globular creature is a sac filled with clear fluid, in which delicately balanced otoliths vibrate. What does the ctenophore feel when the microscopic otoliths lightly touch the sensory cells? We know that this animal has a very primitive type of nervous system and there is experimental evidence that the apical organ responds to mechanical stimuli while it is indifferent to light. To ascertain the nature and extent of ctenophore psychology is a most difficult task. First must come the skilful, patient stimulation of each part of the animal with the most delicate physical apparatus and chemical reagents, varying the light, temperature and other elements of the environment under all the possible conditions of existence. The more difficult part however is the interpretation of the observed results of experimentation. The investigator must now be a philosopher, able to resist the inclination to regard the creature as a mere mechanism because its behavior seems so simple, and on the other hand not yielding to the temptation to project his own mind into the ctenophore when he finds its responses are an elementary edition of his own. That such primitive organisms have the psychic, just as they have the assimilative excretory, respiratory and reproductive functions,



THE CLIFFS OF SKAFTÖ.

is demanded by the logic of the law of evolution. But just what they feel and to what degree they think is largely unknown. In the solution of these fascinating problems enduring biological research will give us knowledge where metaphysical speculation has left us groping and fencing with a jargon of terms.

Among the general problems to be solved in marine stations none are more interesting than those concerning the countless millions of organisms, that float in the surface waters as the plankton. Professor Théel has investigated these matters in the neighborhood of Fiskebäckskil since 1874 and has published important conclusions as to the origin and fate of the plankton. While most of these organisms constitute the holoplankton, always swimming freely, yet many, especially in the breeding season, belong to the meroplankton, swimming as larvæ only part of the time and then going to the bottom to form the benthon population, or to become anchored for the rest of life like the corals. One mystery at Kristineberg is that while many chætopod worms live in the bottom ooze their swimming larvæ appear but rarely in the plankton. On the other hand some forms occur at times in such masses as to make the water thick. Here, as on other seashores, the phosphorescent protozoan *Noctiluca miliaris* has been cast up in windrows of glowing greenish blue living fire. This tiny creature, in common with many other organisms, emits light when touched or rolled about, or upon chemical or electrical stimulation. It is possible on a dark night to read by their phosphorescence, which after all is but a secretion of their photoplasm on fire.

In the bay near Kristineberg from 1890 to 1900, the irregular sea-urchin *Echinocardium cordatum* occurred in large numbers but in the summer of 1902, none of the adults were found and only the young of one centimeter, or less, in size. It is the view of Professor Théel that in such cases, during some unfavorable years, the currents of the sea bear the swimming larvæ away from the ancestral breeding ground where, during their metamorphosis, they may be eaten by hungry hunters, or else sink in the abysmal waters and perish. If they find favorable bottom they will there establish a new race while the old unreplenished parent stock dies out. Thus in 1902 new larvæ of *Echinocardium* came to Kristineberg bay and reestablished the colony in its former home.

So animals appear and flourish in a region only to die out, while others come in to take their places. The rise of the herring fishery in these waters within the last forty years has seen the decline and practical extermination of the oyster business. In view of the fact that the planktonic larvæ, while free-swimming yet depend upon the sea-currents to place them upon the right bottom, it is no wonder, that many perish in the constant struggle for existence. It is only because of the

enormous production of eggs that the species does not die out. If, for instance, only one half of the descendents of one pair of cod-fish should survive, then in the third generation the whole Atlantic Ocean would be packed full of cod-fish! So overpopulation brings its own dangers when members of the same species must fight for space and food and kill one another, or migrate to new regions, before the marvelous balance in nature is readjusted.

Standing in the west wind, on the ocean-ward cliffs of Skaftö, one feels the deep-stirring obsession of the sea. It is no wonder that the Vikings could not resist the siren call of wind and wave. To-day their descendants Lovén, Nordenskiöld and Nansen, sailing forth into the great unknown, have made conquests in the realm of nature that will endure forever.

ERNST HAECKEL: DARWINIST, MONIST

By Professor VERNON LYMAN KELLOGG
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IN 1859 Darwin's "Origin of Species" appeared, and the struggle was on. In 1862 Huxley began his active participation in it, a participation brilliantly maintained until his death. In 1863 Haeckel, before an association of German naturalists in Stettin, declared the Darwinian theory to be the greatest step forward in the study of life that had been taken in modern times; and he prophesied for it the same importance in the understanding of organic nature that Newton's law of gravitation had had in the understanding of the inorganic world. Steadily, since that day, Haeckel has been carrying on the fight for Darwinism and its corollaries.

Of greatest popular interest among these corollaries or logical conclusions and most opposed by all tradition and ecclesiastic and metaphysical authority are, first, the direct descent of man from the lower animals, with all his attributes mental and spiritual as well as physical; and, second, a strictly monistic conception of the world as opposed to the old strongly-established dualistic conception. As Huxley was in England, so Haeckel is in Germany, the special battling champion of the theory of descent and its conclusions. And even more conspicuously than Huxley, Haeckel has maintained and fought for the revolutionary and "irreligious" logical conclusions of the full acceptance of the theory of cosmic and organic evolution.

Such a complete acceptance unites God and nature into an indissoluble unity, even as it does matter and force, body and soul. It leaves no place in one's philosophy for a supernatural, creating God, or for a distinct and peculiar vital force or for a personal immortality of the soul. It accepts completely the cosmic and organic evolution explanation of the earth and its life, holding that life originated on the cooling earth naturally out of non-living materials "by catalysis from colloidal carbohydrogen combinations," and that man is, in his entirety, the outcome of biological transformation, his nearest relatives among living animals kinds being the tailless apes.

Obviously the man who should stand as the champion in poetic, metaphysical, religious Germany of such a *Weltansschauung* must be a man of unusual strength to stand at all, much less to make head against the great forces that would necessarily bar and dispute his way; indeed would combine to overwhelm and trample him under foot. Haeckel has

certainly shown great strength and great courage. Since 1863 he has been, and in this his seventy-sixth year still is, the champion who has almost single-handed made the open fight for the evolution conception and for that complete and extreme dominance of it in sociology, philosophy and religion which he terms monism. And he has made this fight with such success that the two chief opposing combatants, "throne and altar," as he terms them, see in him one of the greatest dangers in the world to their special interests. For Haeckel is no longer merely the German champion of Darwinism and monism, but the world champion. The heresies of "The Riddle of the Universe" and "The Wonder of Life" have penetrated all lands and circles of reading and thinking people.

Born in February, 1834, and educated soundly in a Jena gymnasium and then in the universities of Jena, Würzburg and Berlin, Haeckel early showed his strong predilection and special capacity for the study of nature. He was fortunate in coming in these early formative years under the direct tuition and into the close personal companionship of some of Germany's greatest naturalists. He was variously student and assistant of Schleiden, Alex. Braun, Albert Kölliker, Franz Leydig, Rudolf Virchow, Carl Gegenbaur and Johannes Müller, a brilliant array of names, and a guarantee for the young naturalist's thorough grounding in the facts and principles of botany, zoology, physiology and medicine. Haeckel's first love was botany, but his father's wish led him to make his degree (M.D., Berlin, 1857) in medicine. The later semesters of his university work and his doctor's dissertation were, however, given to zoology, and it was as an active investigating zoologist that he began his post-student career. This career opened with a year's trip to Sicily, where Haeckel commenced that study of the radiolarians, minute shell-secreting one-celled animals, which he has continued as an authority all through his life. This zoological journey was the first of many, especially to tropic lands and waters, that Haeckel has made, the last one being an expedition to Java and Malay in 1900–1901 in search of prehistoric man!

For forty-five years he has taught, investigated and written in the small Thuringian University at Jena. His calls to larger universities he has steadfastly refused, to remain with the institution that has given him from the first full freedom, if not, perhaps, always full faith and adherence. In the earlier more critical years of his bold declarations and the bitter attacks they excited he felt himself becoming an incumbrance, possibly an actual danger, to his university, and he offered to resign his professorship. But the head of the corporation, Seebeck, said to him: "My dear Haeckel, you are still young and you will come to a riper understanding of life. Anyway, you will do less harm here than elsewhere, so stay!"

In quiet little Jena, then, Haeckel's many and extensive and valuable investigations have been carried on and from here has issued that long and brilliant array of monographs, books and published addresses that has excited variously the admiration, the wonder, the scorn and the bitter anger of the world. Like Huxley, Haeckel is most widely known to the world, and to the lay world almost solely, by his more popular and generalizing books and by his brochures and pamphlets dealing with his philosophical propaganda. But also like Huxley, Haeckel has to his credit a large and important original contribution to zoological science. This contribution consists of monographs on the classification and general biology of the protozoans, sponges and medusæ, and represents an extraordinary industry and devotion. And it is largely on a basis of the revelations of the methods and truths of nature as revealed to him in this personal original work that Haeckel claims to have come to his radically monistic world conception.

I do not wish to over-paint the likeness between Huxley and Haeckel. The differences are obvious. The German has more egoism in him. Haeckel fights more for himself; perhaps he has to. His position has a certain difference. But in his polemic he is inclined to more personal defense, more personal reference, more personal exploitation. It is a trait that becomes even slightly uncomfortable for his admirers to face. And Haeckel has had more criticism from his scientific confrères to meet than Huxley had. These brother critics, not gentle ones, accuse him of a certain carelessness in his handling of biological facts. The sharper ones call this carelessness willful overlooking and distortion. His published illustrations are accused of inaccuracies favorable to his argument. He is reproached of a too lively imagination exercised in filling in gaps in his ancestral series with plausible hypothetical links. He gets too swiftly to generalization; he is too speculative. "Der Haeckelismus in der Zoologie" has been for long the subject of much strong writing and talking among German biologists.

But there is no doubt of the unescapable truth of all the larger biological facts upon which Haeckel builds his philosophy and his "scientific religion." The criticisms of this superstructure and its manner of rearing are more to the point than the picking of flaws in the details of phyletic arrangement or embryologic description. And it is these criticisms of Haeckel's monism, Haeckel's materialism and atheism that interest the world at large.

These criticisms are of various types. Some are simply bitter denunciation and epithet, coming mostly from bigoted church men. They have no interest more than a future historical one, nor any real value. They harm neither Haeckel nor his philosophy. Another group of criticisms is less bitter and more would-be analytical and reasoned. But

the critics are misinformed; they lack the knowledge of science and modern *Natur-philosophie* necessary to enter the lists with any strength. These critics are less bigoted and more intelligent churchmen and philosophical dilettanti. Finally there is a third type of criticism, becoming now, with the startlingly swift spread of monistic acceptance among the German people, more abundant and important in character. It is the criticism, keenly analytical, strongly put, of professors of philosophy, liberal and informed clergymen and scientific dualists like Oliver Lodge.

But still more to be reckoned with by the monists in their attempt to remake the philosophy and religious belief of the world is the strong and positive, if less outspoken and active antagonism, of all those who are deeply imbued with the feeling that a religion or philosophy which does not distinguish soul from body and which denies any hope for a persistent life for the soul is a conception in some way negatived by the very life and consciousness of man.

Haeckel manfully, even joyously, faces all these kinds of criticism and charges valiantly against the forces of entrenched belief. We can not too much praise the fighting qualities of this champion. He is a world-figure; at any rate he looms a world-figure in German eyes. We can hardly understand in America how much reading and attention are given by the whole body of German people to the serious problems of philosophy and religion. Haeckel's books and pamphlets are issued by scores of thousands and eagerly read. The "Lebensräthsel" alone is in its two hundred and fiftieth thousand. And in all the bookshop windows are displayed the pamphlets answering and denouncing the atheist philosopher of Jena. The Haeckel and monism subject is only second in interest to the eternal problem of the Kaiser temperament!

Through it all one turns with keen interest to the kindly-faced white-haired figure of the protagonist. Seventy-six years old and still[1] carrying on steadily the duties of his professorship, lecturing simply to students, speaking occasionally to popular assemblies and uttering steadily in direct and plainest sentences his iconoclastic and radical philosophy. His hearers and admirers and followers come chiefly from the lower and middle classes, and especially from the ranks of the growing social-democratic party. He is essentially a people's prophet. Actually how large his following is it would be difficult to say, but the tremendous demand for his writings, all the popularized ones of which are issued in cheap "people's editions," indicates in some degree the number of his adherents. Many of the social-democrats and all the "free-thinkers" take up his cause with enthusiasm, and his "Theses

[1] Since this was written (last winter in Europe) Haeckel has given up his university chair to devote himself exclusively to the care of his new phyletic museum.

of Monism" are the avowed creed of an already large and undoubtedly rapidly growing fraction of the German people. They have besides been "substantially adopted by the Universal Free-thought Congresses of Europe and North America, at Rome and St. Louis, 1904," and are making their way over all the civilized world.

These "theses," as succinctly formulated by Haeckel, number thirty, of which "twenty have to do with theoretical and ten with practical monism." The latter ten are "intended merely to elicit general suggestions according to their subjective interpretations; but the former twenty, namely, "the objectively accepted and established truths of modern science" are considered by Haeckel to be a firm foundation for the monistic conception of the world. These theses affirm (1) that the monistic world conception has its foundation exclusively in scientifically established truths which (2) have been arrived at "partly by sense-observations in the external world and partly by conscious ratiocination in our internal mentality." They deny (3 and 4) that important and profound apperceptions can be gained through supernatural revelation or through *a priori* reasoning independently of experience. They recognize (5, 6, 7 and 8) the dynamic unity of the cosmos, and its government by unchangeable natural laws, denying the dualistic world conception of a material and a spiritual world. Biology is really but a branch of physics, as living matter is subject to the same natural laws that govern dead or inorganic bodies. There is (9) no special or peculiar vital force "directing and controlling the physical and chemical processes within organisms." The whole cosmos is the result of a great monogenetic process of evolution which results in or is an unbroken succession of transformations and variations. This holds for both inorganic and organic nature. "Part of this universal process of evolution is directly accessible to our apperception, while its beginning and its ultimate goal are unknown to us." The world thus (10) was not created by a personal Creator.

The science of organic descent (11) is firmly established, and shows that "all organisms existing to-day on our planet are the transformed descendants of an extensive series of extinct organisms and have in the course of long periods of many millions of years in duration descended from them by evolution." This descent is an established fact whether its causes be explained by means of selection, mutation or any other theory of variation. Organic life (12) began on the earth after the latter had cooled from its molten liquidity into a sphere solidly encrusted with a superficial temperature below the boiling point of water. Life then originated naturally out of inorganic materials "by catalysis from colloidal carbohydrogen combinations." This first life was of the nature of "structureless plasma globules represented in our time by the Chromaceæ (Cyanophyceæ)." By the "grand process of biological

transformation" (13) all the variety of life has come into existence. All this diversified life manifestation is the result of a common physico-chemical process, the metabolism of the plasma. "Its two most important factors are the physiological functions of adaptation (variation) and heredity; the former is related with metabolism (nutrition and growth), the latter with propagation (transgressive growth)."

All organisms are (14) genealogically related and man's place in nature "is fully understood." There is no room left to doubt (15) that man is in every respect a genuine vertebrate, or, more precisely, a mammal and that he has evolved from this highest family of animals not earlier than the latter part of the Tertiary period. Man (16) is plainly most nearly related to the tailless apes, but none of the living representatives of this group can be considered the direct ancestor of man.

On the contrary, the common ancestors of all these anthropoid apes and man are to be looked for in extinct earlier species of apes of the old world (*Pithecanthropus*) or in their relatives.

(17) The soul (psyche) of man taken as a distinct supernatural being in both the mystic realms of metaphysics and of theology, has been recognized as the totality of cerebral functions, a discovery brought about chiefly through the astounding progress made in modern biology and particularly in comparative brain-research. The function of the higher soul or thought-organ in man (pronema)—a certain area of the cerebral cortex—takes place perfectly in accordance with the same laws of psycho-physics in the other mammals, and especially in the nearest relatives of man, the anthropoids. This function, of course, ceases at death, and in our time it appears utterly absurd to persist nevertheless in the doctrine of a "personal immortality of the soul."

Like all other functions of the brain (sensation, imagination, ratiocination), the will of man (18) is a physiological function of this central nervous organ and is dependent on the latter's anatomic structure. The peculiar individual potentialities of the human brain, partly inherited from ancestors and partly acquired through adaptation in the life of individuals, necessarily determine the will. The ancient doctrine of a "free will," indeterminism, therefore appears untenable and must give room to the opposite doctrine of determinism.

(19) If under the ambiguous term of "God" is understood a personal "Sublime Being," a ruler of the cosmos who, after the fashion of man, thinks, loves, generates, rules, rewards and punishes, etc., such an anthropomorphic God must be relegated to the realm of mystic imagery—no matter whether this personal God be invested with a human form or be assumed as an invisible spirit or as a "gaseous vertebrate." For modern science the idea of God is scrutable only so far as we recognize in this "God" the last irrecognizable cause of things, the unconscious hypothetical "first cause of substance."

All these theses are Haeckel's expression of a complete acceptance of the evolution conception and its apparently logical conclusions. Haeckel's constant question is "Do you accept the evolution conception of the world and life?" His constant rejoinder to any who answer Yes is: "Well, then you have to accept, if you are scientifically and philosophically honest, my monism. There is no escape from it."

As a matter of fact, of course, there are plenty of people who accept the evolution conception and do not accept Haeckel's monism. These people do not see that one necessarily follows the other. Many of them indeed think they see that Haeckelian monism does not follow evolution, that it, in fact, has no fundamental connection with it. There are other people still, who are monists, but who do not accept Haeckel's alleged consequences of a monistic, as opposed to a dualistic, conception of nature. But Haeckel undoubtedly believes all he says he does and believes too in the duty of propaganda. That he has a considerable following can not be overlooked.

THE KNOWLEDGE OF GOOD AND EVIL

By Professor T. D. A. COCKERELL
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IN an ancient story, it is told how primitive man ate of the tree of knowledge, and thus lost his original simplicity. "And the Lord God said, Behold, the man is become as one of us, to know good and evil." In later years, we have reason to suspect, our ancestors returned at frequent intervals to the fateful tree, and took therefrom cuttings to plant in their own gardens. The universities, if I mistake not, had their origin in this manner; and it is even possible that the faculties within them have a distant relationship to the serpent of Eden. The modern Adam and Eve are perhaps not so easily beguiled; but, on the other hand, the fruit has been improved by selection and cultivation, and it is no longer necessary to go to the trouble of picking it off the tree; it is served up in dainty dishes, cooked, flavored and predigested. Even those who will not taste acknowledge that it pleasantly stimulates the olfactory nerve.

For all this, the curse has not been lifted. Our animal ancestors were, under ordinary circumstances and for vast periods of time, strictly orthodox. They traveled the straight and narrow path, turning neither to the right nor to the left. Life to them meant the performance of certain acts as their fathers performed them, under conditions such as their fathers enjoyed. Mediocrity—the middle line—was the true standard of excellence. They were not conscious of sin, for they sinned not.

Man, with his dawning self consciousness, found himself in possession of a new power. From this moment he must choose and judge; and thereby usurping the functions of God, be to a considerable extent his own creator. His whole history is a story of how well or ill he played this part, his whole future depends upon his ability to face this responsibility. The ancient curse of failure serves but to spur him on; it is the whip which awakens him from the constantly recurring tendency to sink back into mere animality.

This is the truth at the bottom of the doctrine that all men are evil, and must become conscious of the fact before attaining salvation. Progress depends upon a "divine discontent," and this, like charity, may best begin at home. It has been well said that he who has reached the age of twenty-five without at any time holding himself to be a fool, is indeed one, with small chance of cure. It is a common error to sup-

pose that all great men, standing upon a pedestal above the common herd, are serenely conscious of their perfection; whereas the fact is that these, of all others, are at war, day and night, with their own shortcomings. Just so far as their judgment of good and evil is developed, to that extent must they suffer from a sense of failure. This is true not merely of men, but also of communities; it has been pointed out that the most civilized societies are those which recognize most crime. Acts which our ancestors would have regarded with cheerful tolerance, stir us to spasms of indignation, accompanied by a growing sense of responsibility.

Are we, then, becoming more and more uncomfortable, and is education merely fanning the flame of our discontent? There are, of course, various kinds of so-called education, comparable to the various diseases in their powers of infection. For the purpose of discussion we may assume the view, which I have known to be entertained by children, that genuine superiority depends upon the number of diseases one has had. Develop this idea a little, and suppose universities established for the purpose of giving young people smallpox, scarlet fever, measles and the like. It would be held, of course, that one who had had smallpox was much more educated than one who had merely acquired measles; the latter undoubtedly would be offered in the freshman year. Ostensibly, every one would be anxious to acquire these diseases; but still, it would be privately recognized that they were a lot of trouble, and even sometimes positively dangerous. Hence there would be a strong temptation, when the infection did not take, to sham sickness, and no doubt there would arise agencies selling substances which, placed upon the skin, would produce rashes simulating those of scarlet fever or measles.

Within the university itself, these influences would have their silent potency. Some would come forward with attenuated virus, which though producing scarcely any—or perhaps no—effect, would be declared to be in reality just as good educationally. If one did not believe it, there was proof in the fact that the recipient was subsequently quite immune to the genuine thing. Others would urge, with much show of reason, that the more violent diseases, heretofore offered to seniors, should really only be taken by a small minority of exceptionally talented persons; and anyhow it was not the proper thing to send men out to serve as centers of infection in communities where these particular affections, though undoubtedly of great merit in the abstract, were not at all desired.

All this is absurd, of course; but after all, is there not a similarity between such an educational institution and those which, at present grace the land? Is there no tendency to evade the things which "take," no temptation to simulate an attack while yet in perfect health? I am

not going to be so indiscreet as to specify any of the courses which seem to me relatively or absolutely innocuous; but I am going to assume that our present opinion is, that the knowledge of good and evil is what the university really seeks to impart, and that it accepts, frankly and fearlessly, responsibility for creating shadows as well as light. In a certain sense, it may be said to *produce* evil as well as good; what it really does is to create judgments, whereby these ideas enter the field of human consciousness, in response to the stimulation of objective realities.

The university standard of success, as we must now regard it, is the ability to recognize values. In order to do this, it is necessary to heighten the consciousness of objective reality, and to develop especially a sense of that stability in things which we call truth. It is essential to cultivate imagination, controlled by reason, so that the value of the flower may be seen in the seed, the value of the soul in the form of clay.

Scholarship, culture, judgment, can not be bought at the second-hand store, "a little soiled, but as good as new." They must be created by the fiat of that divinity which we have assumed, re-made from the fruit of the tree in a process of transcendental assimilation.

It is for this reason that I think every university—some day perhaps every high school—should be a center of productive scholarship; not merely of some such, but should glow with the ardor of scientific, literary and artistic creation. Only so may the judgment of fitness be properly established; only thus may the divine gifts be widely received. True it is that comparatively few have strong creative power, such as attracts the attention of the world—but my proposition is that all have some, and that whatever there is, it is the true function of education to develop and sustain it.

This will be more apparent when the scope of recognized scholarship has grown broader. If one may be "a scholar and a gentleman," why not "a scholar and a merchant," or "a scholar and a farmer"? We are beginning to find out, indeed, that these latter professions call for a good deal more scholarship than was necessary for the dilettante gentleman of the old school. When the avenues for creative effort have grown wider and more numerous, and we have learned better to recognize this form of activity under its various aspects, it will no longer be said that all forms of original scholarship are the monopoly of doctors of philosophy.

To those who have tasted of the fruit of the tree, there has never been any doubt of the value of the experience. Whatever the disadvantage, the advantages are enormously greater. The curious point is, that this does not admit of argument, because it is exactly the power of judgment which decides the relative values. So well assured are we of the precious character of our value sense that we would not exchange

it for the whole world; which, without it, would be robbed of all esteem.

It must be confessed that a purely materialistic philosophy—if such a thing were possible—would know nothing of values. It would regard our judgments as it regards all other phenomena, and would point to their endless diversity as proof that they have no special sanction. What it would offer in defense of its own judgment upon this matter, is perhaps not evident.

For ourselves, the diversity of opinion which we find among men is in part the necessary and desirable result of the different angles from which things are viewed, and otherwise the product of that imperfection which is the price we pay for progress. Most of us, perhaps, do not trouble ourselves overmuch about the ultimate sanction, and yet I think that deep down in our hearts we all have some of the feeling embodied in the saying that "One man, with God, is a majority." Without such a philosophy, I am afraid we could not take ourselves quite seriously.

AUSTRALIAN MORALITY

By Professor IRVING KING
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ACCORDING to the earlier explorers and missionaries and the careless travelers of even recent years, the morality of the Australian aborigines was of a very low grade. Almost all such observers agreed in placing them in the very lowest stages of culture. They were described as bestial in habits, naked, lacking all sense of virtue; the men cruel to their children and wives. They were said to be addicted to infanticide and cannibalism, were cruel in their tastes, shiftless, lazy, stupid, deceitful, in fact were possessed of all conceivable evil qualities; they were deaf to the lessons of religion and civilization, ready at theft, and had almost no regard for the value of human life. They were naturally, moreover, given up almost constantly to destructive inter-tribal wars.

The investigations of more recent students of the natural races have thrown a somewhat different light upon the matter. It is now recognized that morality is not to be judged by relationship to some fixed and absolute standard, but rather that it is fundamentally related to the system of social control which holds within the group. It is consequently unjust to apply civilized standards of morality to such peoples. The goodness or badness of an act must be adjudged according to its place within some social context. It must, moreover, be borne in mind that the "higher race," in its first contact with the lower, seldom sees it at its best. Without doubt the ignorance and brutality of many of the first white settlers and explorers of Australia was constantly provocative of retaliation on the part of the natives. The so-called treachery of the latter, their cunning and their dishonesty were merely reflexes of their treatment by the whites. Hence it is impossible to judge of the morals of a race by the acts produced by its contact with another race. It may be admitted that a savage will do many things that a civilized man would not do, but *mere* difference does not render either one or the other immoral. The morality of an act can be determined only when it is known whether it conforms to the standard recognized by the group. This does not, of course, preclude the further inquiry as to whether some social standards are relatively higher than others, but such an inquiry lies beyond the scope of the present article.

In the first place, then, the unfavorable light in which the Australian first appeared is to be explained partly by the treatment he received from the whites and partly from the inability of the whites to understand him. Thus, the laziness of the native may be attributed merely to his inability to fall in with the enterprises of the settlers, or to appreciate the objects of their endeavor or their interests. In activities of their own the natives show the most surprising industry, for example, in the collection of food (Henderson, p. 125), the preparation for and performance of their elaborate ceremonials. The observations which follow should not, however, be taken as applying to the Australian race as a whole, but only to the section directly observed, for there is no question but that there is much diversity in the customs and characteristics of different tribes and groups.

As to personal virtues, the natives of Queensland were said to be generally honest in their dealings with one another. Aside from murder of a member of the same tribe, they knew only one crime, that of theft. If a native made a "find" of any kind, as a honey tree, and marked it, it was thereafter safe for him, as far as his own tribesmen were concerned, no matter for how long he left it.

The Australian native in general was and is possessed of fortitude in the endurance of suffering in a marked degree. There is abundant opportunity for the development of this quality of mind in the painful ordeals of initiation, which ceremony is always accompanied by fasting and the infliction of bodily mutilations of various kinds, differing with the tribe and the locality. These mutilations include the knocking out of teeth, circumcision, subincision and various scoriations of the trunk, face and limbs. Among some of the tribes there are permanent food restrictions imposed by custom upon different classes. There are also food restrictions imposed upon the youth and younger men, and all of these are faithfully complied with, although at considerable personal hardship.[1]

The food restrictions form such an important phase of aboriginal morality that they warrant further discussion. The following regulations of the Kurnai tribe are typical: A man of this tribe must give a certain part of his "catch" of game, and that the best part, to his wife's father. Each able-bodied man is under definite obligation to supply certain others with food. There are also rules according to which game is divided among those hunting together. In the Mining tribe all those in a hunt share equally, both men and women. In all tribes certain varieties of food are forbidden to women, children and uninitiated youths; there are also restrictions based upon the totem to which one belongs. The rules regarding the cutting up and cooking of food are as rigid as those regulating that of which the individual

[1] *Vide* Howitt, p. 561; Fraser, p. 90.

may lawfully partake. Howitt says of these food rules and other similar customs that they give us an entirely different impression of the aboriginal character from that usually held. Adherence to the rules of custom was a matter on which they were most conscientious. If forbidden food were eaten, even by chance, the offender has been known to pine away and shortly die. Contact with the whites has broken down much of this primitive tribal morality.

> The oft-repeated description of the black fellow eating the white man's beef or mutton and throwing a bone to his wife who sits behind him, in fear of a blow from his club, is partly the new order of things resulting from our civilization breaking down old rules (Howitt, p. 684).

Under the influence of the food rules, a certain generosity of character was fostered and unquestionably it was present in the blacks to a marked degree. He was accustomed to share his food and possessions, as far as he had any, with his fellows.

> It may, of course, be objected to this that in so doing he is only following an old-established custom, the breaking of which would expose him to harsh treatment and to being looked upon as a churlish fellow. It will, however, hardly be denied that, as this custom expresses the idea that in this particular matter every one is supposed to act in a kindly way towards certain individuals, the very existence of such a custom . . . shows that the native is alive to the fact that an action which benefits some one else is worthy of being performed.[2]

The apparent absence of any excessive manifestations of appreciation or gratitude in the blackfellow has been interpreted by some adversely. But *giving,* as far as the natives were concerned, was such a fixed habit that gratitude did not seem to be expected. It does not necessarily follow that they could not feel gratitude because they did not show any sign of it to the white man when he bestowed upon them some paltry presents, for, as Spencer and Gillen point out, they might not feel that they had reason to be grateful to him who had encroached upon their water and game and yet did not permit of them a like hunting of his own cattle.

Although as a rule perfectly nude, they are said to have been modest before contact with the whites (Lumholtz, p. 345). Of the north Australians, we are told that the women were never indecent in gesture, their attitude being rather one of unconsciousness (Creed, p. 94f). The low regard for chastity, reported by some observers (*e. g.,* Mackenzie, p. 131), may, in part, be explained by the failure of the outsider to understand their peculiar marriage customs, on account of which the relation of the sexes is to be judged by different criteria than with ourselves. Spencer and Gillen, the most recent and the most scientific of all who have studied this race, say of the central tribes that chastity is a term to be applied to the relation of one group to another

[2] Spencer and Gillen, "The Native Tribes of Central Australia," p. 48.

rather than to the relation of individuals. Thus, men of one group have more or less free access to all the women of a certain other group. Within the rules prescribed by custom, breach of marital relations was severely punished. No one would think of having sexual relations with one in a class forbidden to himself or to those of his own class. It would thus appear that, within the bounds of their own customs, they were extremely upright. When under certain conditions, chiefly ceremonial, wives were loaned, it was always to those belonging to the group within which the woman might lawfully marry.[3] Among the natives of north central Queensland a competent observer (Roth, p. 184) holds that there is no evidence of the practise of masturbation or of prostitution. The camp as a body punished incest and promiscuity. Howitt, writing of the natives of southeastern Australia, says that the complicated marriage restrictions expressed in a very definite way their sense of proper tribal morality. Here also looseness of sexual relations was punished, although at certain times it was proper to exchange wives and at other times there was unrestricted license among those who were permitted to marry (*cf.* Fraser).

Of the treatment of wives and children there are conflicting reports, the more recent investigators holding that there was less cruelty than was at first represented. There was, however, doubtless much difference in this respect in different tribes. One early observer (Earp, p. 127) affirms that wives were always secured by force, the girl being seized from ambush, beaten until senseless, and thus carried off by her "lover." Others, in like manner, emphasize the brutality of obtaining wives (Angas, p. 225). Lumholtz says that stealing was and is the most common method. The researches of Spencer and Gillen do not confirm these statements as far as the natives of central Australia are concerned, while Roth refers to the commonness of the practise of stealing wives and eloping among the north central Queensland natives. According to Spencer and Gillen, wives may have been so secured, but such was assuredly not the customary method in central Australia at least. They know of no instances of girls being beaten and dragged away by suitors. It is probable that cases of exceptional cruelty more easily came to the notice of the first travelers and they inferred that such cases were characteristic. The last named authors affirm that the method of securing wives among these tribes was definitely fixed by tribal usage and involved no cruel practises whatsoever. Howitt, the authority upon the southeastern tribes, says that cruelty was often practised upon elopers, but this is manifestly because they had themselves been guilty of breach of tribal morality. Looseness of sexual relations among these tribes originally always met with severe punishment.

[3] See also Cameron, *Journal Anthropological Institute*, Vol. 14, p. 353.

As to treatment of wives among the central tribes (Spencer and Gillen), there were undoubtedly cases of cruelty, but they were the exception rather than the rule. The savage husband has a hasty temper and in a passion might act harshly, while at other times he might be quite considerate of his wife. Among the aborigines of the Darling River, New South Wales, quarrels between husband and wife were said to be quite rare (Bonney), and Smith says that love is not rare in Australian families, while another observer (Palmer) says that the life of the women is hard and that they are much abused by their husbands. Dawson, who wrote expressly to show that the Australian blacks had been misrepresented, maintained that in Victoria, at least, there was no want of affection between members of a family (p. 37). Lumholtz (pp. 161ff.) holds that the Queensland husband felt little responsibility for his family, that he was really selfish and hunted only for sport, often consuming the game as caught, bringing nothing home. The same author refers to one case of a wife being terribly beaten because she refused, one cold night, to go out and get fuel for the husband. Over against this testimony, we have that of Spencer and Gillen, referred to above, that the husband was ordinarily by no means cruel. In hard seasons men and women suffered alike. A woman, however, suspected of breach of marital relations, was treated with revolting severity. They point out that many things which to us seem harsh were by no means so in their eyes, and that the savage woman recovers easily from wounds that to a civilized woman would entail the greatest suffering. Treatment which we should naturally think cruel was to them merely rough and in conformity with the rest of their life. Howitt (p. 738) says that among the Kurnai tribe family duties were shared by husband and wife, each performing an allotted part toward the support of the family. The man's duty was to fight and hunt, the woman's to build the home, catch the fish and cook them, gather vegetable foods, make baskets, bags and nets.

With reference to their children, much affection was usually shown, and this in spite of the fact that abortion and infanticide were practised in many localities (*e. g.*, in northwestern central Queensland, (Roth, p. 183); and among the southeastern tribes, Howitt, pp. 748ff.). In this connection Howitt says, " . . . they [the Mining tribe] are very fond of their offspring and very indulgent to those they keep, rarely striking them," a mother often giving all the food she had to her children, going hungry herself. Infanticide was by no means so unrestricted, or as indicative of cruelty of nature and lack of parental affection as is implied by Mackenzie, writing in the year 1852.[4] Among the north central tribes[5] infanticide was practised, but only

[4] *Vide*, "Ten Years in Australia," p. 130.

[5] Spencer and Gillen, "Northern Tribes," p. 608.

upon rare occasions at any other time than immediately after birth, and when the mother thought she was unable to care for the babe. The killing of the new-born child was thus an effort at kindness on their part and to them was certainly devoid of cruelty, since they believed the spirit part went back to the spot whence it came and was subsequently born again to the same woman. Twins were killed as unnatural, a practise to be explained in part by the natives' dread of everything uncommon or rare. On infrequent occasions a young child of a few years was killed that an older but weaker child might eat it and thus get its strength. Howitt mentions the same practise among the southeastern natives (p. 749). He also says that in some places infants were eaten in especially hard summers. Sometimes, also, after the family consisted of three or four, all additional children were killed because they would make more work than the women could manage. Among the Kurnai, infanticide unquestionably arose through the difficulty of carrying a baby when there were other young children, some of whom might be unable to walk. Infants, under these circumstances were simply left behind when they were on the march, it not being regarded as killing to dispose of them in this way (Howitt, p. 750). Palmer, writing of the natives of Queensland, says that the killing of a new-born child was lightly regarded, but not common. On the lower Flinders River the fondness of the natives for their children was noted (Palmer). Spencer and Gillen say that, with rare exceptions, children were kindly and considerately treated, the men and women alike sharing the care of them on the march and seeing that they got their proper share of food. Howitt mentions the case of a mother watching a sick child, refusing all food, and, when it died being inconsolable (p. 766). One woman for nineteen years carried about a deformed child on her back (Fraser; vide Henderson, p. 121). Natural affection was certainly keen and much grief was manifested over the loss of children.

In the aborigines' treatment of the old and infirm most observers depict them in quite a favorable light. Dawson, it is true, reports that the natives of Victoria killed them, but this is certainly not a widely prevalent custom. Lumholtz (p. 183) says that the Queenslanders were very considerate of all who were sick, old or infirm, not killing them as with some savage peoples (*cf.* Bonney, p. 135). In northern parts of Australia there were many blind and they were always well cared for by the tribe, being often the best fed and nourished (Creed, p. 94). In the central tribes the old and infirm were never allowed to starve. Each able-bodied adult was assigned certain of the older people to provide with food, and the duty was fulfilled cheerfully and ungrudgingly.[6] In some tribes the old and sick were

[6] Spencer and Gillen, "Northern Tribes," p, 32.

carried about on stretchers. In the Dalebura tribe a woman, a cripple from birth, was carried about by the tribes-people in turn until her death at the age of sixty-six. On one occasion they rushed into a stream to save from drowning an old woman whose death would have been a relief even to herself. Fraser emphasizes the respect in which old age was held by the aborigines of New South Wales, and the fact that they never desert the sick (see also Smith).

Cannibalism among the Australian blacks was by no means a promiscuous and regular practise as was at first supposed. It is true, Lumholtz says of those observed by him, that human flesh was regarded as a great delicacy.[7] Palmer, writing of Queensland also, says that cannibalism was practised to a certain extent; in some sections those killed in fights being eaten, and often children who had died. An early writer reports that in South Australia bodies of friends were eaten on their death as a token of regard.[8] Spencer and Gillen found difficulty in gathering evidence of its being practised among the central tribes. They were often told by one tribe that it was customary among others who lived farther on, they in turn saying the same thing of those beyond themselves. They think, in general, that human flesh was eaten as a matter of ceremony or at least for other than mere food reasons. They found much more evidence of it among the northern tribes. Howitt says the Dieri tribe practised cannibalism as a part of their burial ceremonies, that it was a sign of sorrow for the dead. Among others only enemies slain on their raids were eaten; the Kurnai, for instance, would not eat one of their own tribe. Among still other tribes, if a man were killed at initiation ceremonies he was eaten, as also any one killed in one of the ceremonial fights, and others again did *not* eat their enemies. Howitt is positive that there is no such thing among any thus far observed as propitiatory human sacrifice, and he denies emphatically the statement made current by some that sometimes a fat *gin* (woman) was killed to appease their craving for flesh when they chanced to have been long upon a vegetable diet. He also says that at the tribal meetings of the Bunya, men, women and children, killed in fights or by accident, were eaten, but that there is no evidence that women and children were killed for cannibalistic purposes.

The morality of the Australian native was, in a word, the morality of tribal custom, and, if fidelity to duties so imposed may be taken as a criterion, it was of no low order. Recent investigators unite in testifying that the black-fellow, especially before contact with Europeans, was most scrupulous in his obedience to the sacred duties imposed upon him by tribal usage. Of the Queensland natives Roth says (pp. 139ff.):

[7] See also Bicknell, p. 104, who holds it was quite common.

[8] Angas, p. 225; Fraser, p. 56, as a sign of regard or in ceremonial.

The life of the tribe as a whole seemed to be well regulated. Custom, with the old men as its exponents, was the only law. Where there were few old men, each individual, within limits, could do as he pleased.

Howitt writes of the tribes studied by him that custom regulated the placing of huts in the camp, and even the proper position of individuals within the huts. In the Kaiabara tribe single men and women lived on opposite sides of the camp. The old women kept an ever watchful eye upon the young people to prevent improprieties. In another tribe the women could not come to the camp by the same path as the men, a violation of the rule being punishable by death. The law of custom thus controlled almost every phase of the life of the individual, including many individual matters as well as conduct toward others; the intercourse of the sexes is or was most definitely limited and regulated; the women who were eligible to each man in marriage were also rigidly determined by custom, as well as the proprieties of conduct toward the wife's family. Reference has already been made to the severe restrictions entailed by the initiation and other ceremonies, and also to the minute regulations regarding the choice of food. In all cases these customs were enforced by severe penalties. In some tribes the local group or camp united to punish any member who was guilty of overstepping these bounds as well as complicity in more serious crimes such as incest, murder or the promiscuous use of fighting implements within the camp. Most customs were, however, probably obeyed from habit, the native being educated from infancy in the belief that infraction of custom would produce many evils such as premature grayness, pestilence and even cosmic catastrophes. In fact, among the tribes observed by Howitt authority was generally impersonal, though not always, for the headmen were often men of great personal ability and were greatly feared and respected by the rest of the tribe or group (Howitt, pp. 296–300).

Questions of right and wrong for the Australians seem to have centered chiefly about food restrictions, secrets relating to the tribal ceremonies, the sacred objects and wives. Moral precepts probably originated in association with the purely selfish idea of the older men to keep all the best things for themselves.[9] In this way, at least, may be explained many of the regulations regarding what the younger men might eat. So also as to marriage, for aside from restrictions as to totem and class into which a man might marry, all the younger women were reserved by the old men, the less desirable ones, alone, being available to the young men. But, granting the selfish character of many of the rules, there was still a certain amount of morality which transcended anything of this sort. The old men in their leisure "instructed the younger ones in the laws of the tribe, impressing on

[9] Spencer and Gillen, "Native Tribes," etc., p. 48.

them modesty of behavior and propriety of conduct . . . and pointing out to them the heinousness of incest" (Howitt, p. 300). The rigid duties of manhood centered especially in the ceremonies of the tribe. The obligations which these involved were regarded as extremely sacred and inviolate. "As he (the youth) grows older he takes an increasing share in these (ceremonies), until finally this side of his life occupies by far the greater part of his thoughts" (Spencer and Gillen). He must continually show strength of character, ability to endure hardship, to keep secrets, and, in general, to break away from the frivolity of youth and all that savored of femininity. There were, among the central tribes, certain sacred things which were only gradually revealed by the older men, and if a young man showed little self-restraint and was given to foolish chattering it might be many years before he learned all that was in store for him.

It is interesting to learn that under the traditional régime the Australian natives lived a harmonious and certainly far from unhappy life. Fraser says they were a merry race (p. 43). Howitt, who was instrumental in gathering together the Kurnai tribe for the revival of their initiation ceremonies some years ago, reports that the people lived for a week in the manner of their old lives, and that the time passed without a single quarrel or dispute (p. 777). In their wild state the Dalebra tribe were noted to have lived most peaceably, *e. g.*, a camp of three hundred is known to have continued for three months without a quarrel. Their method of settling disputes was usually by means of a fight between the parties who were at odds. When blood was drawn, the fighting ceased and all were henceforth good friends (Dawson, p. 76). They were generous in fighting, taking no unfair advantage. They loved ease and were not quarrelsome, but were nevertheless ready to fight (Smith, p. 30, Vol. I.). Mortal wounds in such conflicts were rare (Lumholtz, p. 126). Spencer and Gillen likewise say of the central tribes that whenever compensation in any form had been made by an offending party the matter was ended and no ill-will was cherished (p. 31).

In some tribes theft was regarded as the greatest crime aside from the murder of a fellow tribesman. As there was so little private property, however, crimes arising from this source were rare. The stealing of women is said to have been the most common cause of inter-tribal trouble.[10] There were no fights for superiority, no suppression of one tribe by another. Within the tribe there was, in large measure, absolute equality. There were no rich or poor, age being the only quality that gave preeminence (Semon, p. 225). The inter-tribal fights were certainly not so serious as some have represented. That they were constantly attacking and trying to exterminate one another is not con-

[10] Lumholtz, p. 126; Spencer and Gillen, "Northern Tribes," p. 31.

firmed by those who have known them best. Their fights were probably half ceremonial or of a sportive character and they were usually stopped when blood flowed freely.

They undoubtedly did fear strangers, and a man from a strange tribe, unless accredited as a sacred messenger, would be speared at once.[11] On the other hand, delegations from distant tribes were received and treated with the utmost kindness if they came in the recognized way. They were even permitted to take a prominent part in the ceremonies of their hosts.

The relations subsisting between members of the same tribe or group were, according to Spencer and Gillen, marked by consideration and kindness. There were occasional acts of cruelty, but most of them can be attributed to something else than a harshness of character. Thus, much cruelty resulted from their belief in magic (The Central Tribes, p. 48). The revolting ceremonies practised at initiation were all matters of ancient tribal custom and hence cast little reflection upon the real disposition of the native.

All things considered, we are obliged to say that their life was moral in a high degree, when judged by their own social standards, and not even according to our standards are they to be regarded as altogether wanting in the higher attributes of character. Dawson holds that, aside from their low regard for human life, they compared favorably with Europeans on all points of morality. Howitt says (p. 639):

> All those who have had to do with the native race in its primitive state will agree with me that there are men in the tribes who have tried to live up to the standard of tribal morality, and who were faithful friends and true to their word; in fact, men for whom, although savages, one must feel a kindly respect. Such men are not to be found in the later generation.[12]

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THE GEOGRAPHIC ASPECT OF CULTURE

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THE dynamic influence of geography in history has recently attracted general attention. The idea was developed from a philosophical standpoint by Hegel,[1] about the middle of the last century, but only recently has it come to be regarded as of special significance. In the light of the discoveries of Hedin[2] and Huntington[3] in central Asia, however, there can be no doubt that the characteristics of primitive races are profoundly modified by environment. As an instance of this, Huntington has shown that the Kirghiz nomads inhabiting the deserts and plateaus of the Lop Basin in Chinese Turkestan are forced to lead a roving life by reason of the scantiness of subsistence. This in turn limits their occupations to the manufacture of portable articles such as rugs and felts, while it also accentuates certain characteristics such as hardihood and hospitality. In contrast to this type, the Chantos inhabiting the oases are tied down to intensive agriculture, the effect of which is also distinctly apparent in their character and occupations. This is further intensified by the lack of sufficient rainfall, which in their case has imposed such a severe limitation upon increase in population as to have given rise to the institutions of monasticism and polyandry.

The United States also furnishes a notable instance of the effect of physiographic environment.[4] The colonization of America was in itself a matter of latitude, the tier of early colonies along the Atlantic seaboard following practically the same arrangement as their European prototypes. Again the barriers of sea and mountain gave coherence to the New England colonies, which, reinforced by favorable latitude, ripened the spirit of independence. Other natural features, such as the great river valleys and mountain passes, were instrumental in determining the great trade routes, as well as in shaping the campaigns of the revolution and the civil war.

In connection with topography, the related factor of climate is also

[1] Hegel, "The Philosophy of History" (1st ed., 1837), English translation, Bell & Sons, 1902.

[2] Hedin, "Central Asia and Tibet," Scribners, 1903.

[3] Huntington, "The Pulse of Asia," Houghton, Mifflin, 1907.

[4] Semple, "American History and its Geographic Conditions," Houghton Mifflin, 1903.

of primary importance.[5] In polar and tropical regions, as well as in certain other isolated sections such as the deserts of central Asia, it is an absolute barrier to progress. Even in the most favored localities it has a marked effect upon the trend of social evolution. The invigorating effect of clear, cold weather is commonly recognized, but it is equally true that excessive moisture depresses the vital processes and thereby hampers development, an effect strikingly exemplified in the case of Ireland. On the other hand, dry weather if sufficiently prolonged creates a surplus of energy and at the same time weakens the emotional control, resulting, as shown by statistics, in a notable increase in misconduct and crime, apparent not only locally in times of drought, but habitually in dry countries like Mexico.

A remarkable synchronism of climatic changes has also been shown to exist throughout the world, recurring in cycles of approximately thirty-six years. In America this has made itself felt in the great financial crises, each of which has been associated with the deficiency in rainfall occurring at the low point of one of these cycles. This in turn has reacted upon politics to such an extent as to be of national import.

As yet the study of geographic influences in history has related only to such external and obvious manifestations as are apparent in social, industrial and political development. It may be interesting, therefore, to point out how these results may be extended to include intellectual development. In any attempt of this kind, it is necessary at the outset to set up some universal and fundamental principle of thought to serve as a standard for comparison of racial traits, and an index of mentality. Since racial traits become more distinct and divergent the more remote the period considered, few principles are sufficiently general to answer this purpose. There is, however, at least one form of thought which has always been characteristic of the human mind wherever historically manifested. Primitive culture, however remote, has always been accompanied by some form of mathematical reasoning. It is, in fact, noteworthy that all oriental nations ascribe the origin of both their culture and their mathematics to a single personage whom they also regard as the founder of their race. With the Chinese this was the Emperor Fohi, whose reign, about 2800 B.C., marked the beginning of Chinese history. As the Chinese have no earlier records to indicate the origin of their mathematics, their traditions relate that the number system was revealed to this emperor inscribed on the back of a dragon which rose from the waters of the Yellow River. In Egyptian history the first historical personage is the King Menes, who ruled somewhere between 5000 and 3000 B.C., and was the founder of the first dynasty of Pharaohs. Here also, from lack of earlier records, the Egyptians regarded Menes as the father of numbers, calculation and writing.

[5] Dexter, "Weather Influences," The Macmillan Co., 1904.

Even such an enlightened and careful historian as Josephus relates that Abraham taught mathematics to the Jews, and instances might be multiplied to show that this idea is prevalent throughout history.

The intimate connection of mathematics with early culture is further apparent in its relation to religion and philosophy. In Egypt mathematics was the peculiar possession of the priesthood, and was guarded by them with the utmost jealousy. When it passed to the Greeks it was made by them a prerequisite for philosophical study, their great philosophers being primarily mathematicians. At the beginning of the christian era mathematics again passed into the keeping of the priesthood, its preservation during the dark ages being due to the care with which it was preserved in catholic monasteries. Even the pope openly gave it the sanction of the church, threatening Galileo with the Inquisition for his heretical astronomical doctrines, and refuting them by issuing a manifesto to the effect that the sun moves around the earth in accordance with the time-honored Ptolemaic system. During the period of the reformation, mathematics was regarded as one of the most powerful weapons of Protestantism, many noted mathematicians of the time devoting all their efforts to proving that Pope Leo X. was the antichrist mentioned in Revelation 13: 18.

The history of mathematics begins in the valley plains of Egypt. On this border line between the tropical and temperate zones, climate and soil were so adapted to the needs of primitive man as to force intellect to its earliest manifestation. As Aristotle expressed it, "When pressing needs are satisfied, man turns to the general and more elevated," and consequently, as Hegel points out, the temperate zone is the true theater of history, since where heat or cold are intense, external pressure is never relieved. As the rigors of climate lessened and man attained a greater mastery over nature, these two factors conspired to force culture out of its primitive seat in the river valleys of the Nile, Tigris and Euphrates towards the northwest, its northerly progress being determined by climatic changes, and its westerly course by topographic features. If the course of mathematical development is traced out on a physiographic and isothermal map, it will be clearly apparent not only that it has followed the lines of least resistance topographically, but that it has crossed successive isotherms in its northerly progress with great regularity, due, as has been suggested, to the increasing need of the nervous system, as it becomes more complex, for a more bracing climate.

The three chief geographic features which exhibit fundamental differences are valley, mountain and sea. In the valley plains of China, India, Babylonia and Egypt, the fertility of the soil assured a plentiful subsistence, while the regularity of the seasons, combined with landed values resulting from agriculture, gave rise to a fixed social relationship. In more elevated regions, such as the plateaus of Africa and South

America, and the steppes of Russia, the scarcity of subsistence necessitates a nomadic life. In this patriarchial form of existence the size of the community is limited by the productiveness of the soil, as illustrated in Genesis 13: 5–11. Fixed relationships are therefore unknown, and hence the political and social order called the state is impossible.

Each of the great river valleys of antiquity developed an independent civilization, Egypt first by reason of its tropical location, closely followed by China and the Tigro-Euphrates basin, lying five degrees farther north. The beginnings of Chinese culture were equally promising with those of the other great nations of antiquity. The art of writing was probably originated by the Chinese, while the elements of mathematics and astronomy, the art of printing and various manufactures, were known to them centuries before they reached Europe. The geographical isolation of China, however, put an effectual barrier to progress, resulting in a sort of inversion of character, whereby reverence for precedent took the place of progressive development. As an instance of this inversion, it is related of one of the Chinese emperors that when he wished to confer honors upon his prime minister he conferred them upon the minister's father. Chinese culture has petrified almost at the outset, and is therefore of no significance except as a case of arrested development, due largely if not wholly to geographic limitations.

In contrast to China, the civilizations originating in the valleys of the Nile and Euphrates found a natural outlet eastward and northward by way of the Mediterranean. Here culture in all its phases reflected the influence of the soil. Religion took the form of a gross nature worship, the divinities being the great rivers, the sun and moon, and other natural sources from which their physical wants were supplied, while arts and manufactures were also limited to the practical and prosaic. In Egypt the peculiar physical conditions presented by the annual overflow of the Nile led to the invention of surveying, and of necessity to the elements of arithmetic and geometry required to apply it. In architecture also the effort to orient their temples gave rise to certain fundamental geometric theorems, still in use, such as the properties of right-angled triangles, while in art the enlargement of small drawings or paintings for their temple walls was accomplished by means of a network of squares closely related to the modern Cartesian system of coordinates. The entire absence of rainfall and consequent clearness of atmosphere also had an important effect in directing the attention of the Egyptians to the heavens, which, supplemented by the oriental use of the roof as a terrace, led to the study of astronomy.

In Chaldea the similarity of race and physical conditions to those in Egypt led to identical results, the earliest fragments of Chaldean literature disclosing a considerable knowledge of mathematics, astron-

omy, architecture and various practical arts and manufactures. The Assyrian temples were adjuncts of the palaces, and were also used as observatories where the priestly astrologers consulted the stars and cast horoscopes. Even before Abraham left Ur of the Chaldees, that city possessed a royal observatory and a calendar. In short, action was based upon nature, although interpreted by each race in accordance with its racial characteristics. Thus, with a more esthetic people, out of door life under the clear skies of Judea found expression in the poetic description of the heavens embodied in the Hebrew Psalms, instead of in the practical astronomy which the Egyptians and Assyrians associated with their religion.

"Egypt and Assyria," said Lenormant, "were the birthplaces of material civilization; the Phœnicians were its missionaries." This describes in brief the part taken by the Semitic race occupying the little strip of seacoast, 180 miles long by 12 broad, on the eastern littoral of the Mediterranean in transmitting ancient civilization to Europe. Here again the geographical element was strongly apparent, both subjectively in their national culture and objectively in their relation to history. While the effect of mountain ranges was to shut off such regions as central Africa, eastern Asia and northern Europe from the general course of historical development, and that of the great valley plains was to intensify human activity, the sea formed a bond of union and at the same time stimulated bravery, independence and breadth of vision. To this characteristic difference between coastal and interior regions is due their frequent separation, as, for example, Holland has separated itself from Germany and Portugal from Spain. The influence of the sea was especially apparent in the development of the nations surrounding the Mediterranean. Here were three continents surrounding a sea of such shape as to afford a long coast line and of such width as to stimulate adventure. The effect was to make the Mediterranean the center of world history. On its shores arose the great centers of civilization, Athens, Rome, Carthage and Alexandria, as well as of religious faith, Jerusalem, Mecca and Medina.

The geographical location of Phœnicia, midway between Egypt, Assyria and Arabia, naturally made it first to develop commercial activity. From their rich commercial cities of Tyre and Sidon the Phœnicians pushed out in all directions, settling Cyprus, Sicily and Sardinia, founding Cadiz in Spain, and Utica and Carthage in Africa. As early as 1500 B.C. the Mediterranean was already the great highway of Phœnician commerce, their vessels penetrating the eastern archipelago, the Hellespont and the Black Sea. When these avenues were closed to them by the Greeks in the eleventh century B.C., the Phœnician commerce turned westward, bringing silver from Tarshish in southern Spain, and even passing the Pillars of Hercules and braving the perils of the Atlantic to bring tin from Britain and amber from the Baltic.

In connection with their maritime trade they also established great overland routes, their caravans bringing gold from Ophir in southeastern Arabia, and passing through Palmyra, Baalbec and Babylon, whence they penetrated all the east.

Although the Phœnicians were thus brought into intimate contact with all the great nations of antiquity, their culture was essentially different. Forced to rely upon the sea for their livelihood, they developed an industrious and hardy manhood in marked contrast to the dependent attitude characteristic of nations relying upon agriculture for their subsistence. In religion the same contrast was apparent, the religion of the Egyptians and Assyrians being a crude and sensuous idolatry, whereas the Phœnicians worshipped Hercules, a divinity whom the Greeks said raised himself to Olympus by virtue of his own courage and daring. In mathematics the Phœnicians developed commercial arithmetic, necessitated by their enormous commerce. According to Strabo, the Syrians applied themselves especially to the science of numbers, navigation and astronomy. They were, in fact, the first to notice the connection of the moon with the tides, and make a practical application of astronomy to navigation. It is also said that the Phœnicians regularly supplied the weights and measures used by their neighbors, the Chaldeans. In all respects, therefore, their culture was a natural consequence of the commercial spirit engendered by the sea.

With the rise of Grecian culture, a new topographical principle entered to alter the trend of development. Numerous mountain walls fence off the Grecian peninsula into a large number of isolated districts, each of which became the seat of a separate community or state, which never coalesced into a single nation. Moreover the coast is indented with numerous deep inlets, forming excellent harbors and giving every inducement to commerce. So numerous and deep are these inlets that the country is practically an archipelago, no place in Greece being forty miles from the sea. To this combination of mountain and coastal elements was largely due the versatility of the Greeks, while the exhilarating atmosphere and brilliant skies of Attica were also intimately related to their intellectual vigor and attainments.

The same principle of diversity is also met in the origin of the Greeks. There was here no such inbreeding of native stock as characterized Egypt and China, but at the outset a mixture of races, partly autochthonous and partly foreign, from which there evolved a higher type of intellect than had yet appeared. The diverse sources of their civilization was acknowledged by the Greeks in their mythology. Thus the introduction of agriculture was ascribed to Triptolemus; fire was introduced by Prometheus from the Caucasus; Æschylus speaks of iron as "Scythian"; while Poseidon introduced the olive, the horse and the arts of spinning and weaving. The foundation of the various states was also ascribed to foreigners. Thus Athens was said to owe

its origin to Cecrops, the Egyptian; the Peloponnesus derived its name from Pelops, of Phrygia; Argos was settled by Danaus, of Egypt; and Thebes by Cadmus, of Phœnicia. Even their religion was borrowed from more ancient nations. For example, the twelve labors of Hercules rests upon the ancient idea of the sun performing its cycle through the twelve signs of the zodiac.

With the general shifting of the tribes which succeeded the Trojan War, the Dorians and Ionians came to be the dominant races of Greece. The Dorian band which invaded Lacedemon, called also Sparta from its grain fields, was at first forced by the scantiness of its numbers to be constantly on the defensive, which developed in them the warlike and hardy spirit which finally made the Spartans dominant in the Peloponnesus. The Ionians inhabited Attica, where the contending geographic factors of plain, coast and mountain transformed their original monarchy into a democracy, and their little fortress upon a rock into the mighty Acropolis of Athens, for centuries the synonym of learning and democracy. "The Athenians," said Herodotus, "then grew mighty, and it became plain that liberty is a brave thing."

No phase of Greek culture was more expressive of their national characteristics than their mathematical attainments. Heterogeneity, which formed the basal element of their national character, was here apparent in the diverse sources from which their mathematics was derived. Thales, the first great Greek mathematician and the founder of the Ionian School, was a native of Miletus, but spent much of his life in Egypt as a merchant, where he studied geometry and astronomy. Pythagoras, who was a contemporary of Thales and founder of the Pythagorean School, was of Phœnician origin, and in his early life studied for several years in Egypt and traveled extensively in Asia Minor. The Ionian and Pythagorean schools were jointly the founders of Greek mathematics, which took the form of an abstract deductive geometry, as distinguished from the practical empirical geometry of the Egyptians. It was, in fact, the boast of the Pythagoreans that they sought knowledge and not power, and had raised mathematics above the needs of merchants. One of their maxims was, "a figure and a step forward; not a figure to gain three oboli." The disciples of Pythagoras were required to pass through a preliminary training, consisting in a moral and religious preparation for life, which included the elements of music and mathematics. In fact Pythagoras made the science of numbers the basis of his philosophy in the belief that accurate measurement was essential to the definition of form, and consequently that the entire universe was founded upon a numerical basis. Thus among other attributes of number, the cause of color was the number 5; the origin of fire was to be found in the pyramid; the four elements, earth, air, fire and water were represented by the tetrad; 8 was the symbol of

death, because the sum of the figures in the successive multiples of 8 decreased successively by one; 9 was the symbol of immortality, since the sum of the figures in the multiples of 9 remains constant, etc.

Plato, the great philosopher of the later Athenian school, also regarded mathematics as the basis of his philosophy, placing over his door the famous inscription, "Let none ignorant of geometry enter here." It is also noteworthy that when he was questioned as to the occupation of the Deity, Plato replied, "He geometrizes continually." This lofty idealism was characteristic of Greece and entirely foreign to the prosaic civilizations of Egypt and Assyria. Only the combination of sea, mountain and climate found in Hellas could produce the unique type of the Grecian genius. This dependence of type on surroundings is evidenced by the fixity of type apparent in ancient races. Thus the Fellaheen still bear the imprint of the Pharaohs on their countenances, and draw water with the Shadoof as at the dawn of history, while the Chinaman is still found reckoning with the beaded "swan pan," invented twenty-six centuries before Christ.

Passing from Greece to Italy, as the next stage in the evolution of culture, another great change is manifest. Italy presents no such natural unity as offered by the valley of the Nile and the Tigro-Euphrates basin, nor does it present the diversity of Greece. A narrow peninsula bounded by the sea on three sides and lofty mountains on the fourth, the physical peculiarities of Italy naturally cemented the diverse tribes with which it was originally peopled into a single state. The origin of the Imperial city dated from a predatory band of Latin shepherds who received into their community the outcasts of the neighboring tribes, so that even at the outset the dominant idea was that of physical force, a principle which pervades the whole fabric of Roman civilization. The rape of the Sabine women confirms the tradition that the band, being without women, was a predatory union of outcasts, or what Livy calls a "colluvies." The growth of the Roman state was throughout a process of accretion, rather than the unfolding of a vital principle. The civilization of the Romans was likewise due to this policy of absorption, borrowing their religion and culture from surrounding nations. But while the gods of the Greeks and the Egyptians found a home on the banks of the Tiber, they were there worshipped in a spirit entirely foreign to that of their nativity, for whereas the Greeks worshipped their divinities from an innate love of abstract beauty, the Romans worshipped the same gods from a spirit of necessity, bargaining with them for physical protection and material success. Again, although the Romans borrowed the Grecian games, they had no idea of the esthethic pleasure derived by the Greeks from perfect physical development, but degraded them into mere gladiatorial combats or exhibitions of brute force in which they were spectators and

not participants. Science and art were neglected, and in literature they were largely indebted to the Greeks. Only in building and public works did the practical spirit of the Romans assert itself with any originality. Even here outside assistance was relied upon to furnish the necessary technical skill, the order issued by Augustus Cæsar that all the world should be taxed being based on a survey by Egyptian surveyors.

The fifth century A.D. was known as the "Era of the Great Migration." Owing, it is supposed, to climatic changes, the Teutonic tribes inhabiting the great central plain of Europe were forced outward, and poured east and south into the Roman empire. So great was the disturbance occasioned by this outbreak that nearly two centuries elapsed before the turbulance subsided sufficiently to note the changes that had taken place. Meanwhile an invasion from the east threatened for a time to give an Asiatic cast to civilization. With the fanaticism bred by the inaccessible deserts of the Arabian peninsula, the Saracens in the seventh century swept westward until they reached southern France, where the tide was finally turned by Charles Martel on the field of Tours. No less astonishing than their conquests was the facility with which the Arabs assimilated the culture and learning of the nations whom they subjugated. Their capitol Bagdad, situated on the Euphrates midway between Greece and India, soon became by reason of its location the meeting place for the scientific thought of these nations, whence it was transmitted by their conquests to western Europe. The mathematical attainment of the Arabs was, however, distinct from those of either Greece or India, its trend being determined by their religious observances. Thus the extent of the Moslem dominions coupled with the requirement that a believer should face toward Mecca during prayer, made a determination of direction necessary. Also the performance of prayers and ablutions at definite hours of the day and night required an accurate determination of time, while the motion of the moon had to be observed in order to fix the dates of their feasts. From these and similar reasons the Arabs became active in astronomical research, and in consequence developed the auxiliary science of trigonometry.

The turmoil attendant upon the invasion of the ancient world by the Teutons and Saracens so obscured the progress of civilization that this period, although in reality one of beginnings, is known in history as the Dark Ages. The most important feature of this vast influx of barbarians, so-called, was the rapid conversion of the Teutons to Christianity. A colder climate had bred in them a more vigorous mentality and a higher type of morality than that of the south, and Christianity appealed with especial force to their innate love of freedom and spirit of brotherhood. History thus far had been a record of the physical

evolution of humanity. Egypt, China, Chaldea, Assyria and Babylonia typified the childhood of the race with its characteristic dependence upon nature apparent even in its culture; Greece with its love of form, self-consciousness and passion for freedom represented the adolescent stage; while physical development culminated in the forceful and prosaic Roman spirit, typical of manhood. The birth at this time of the Child, in Bethlehem in Judea, was then not a casual event but a necessity. The first Adam had been made a living soul, and in slow process of time had attained his majority. The second Adam was made a quickening spirit, creating a new form of energy which thenceforward was destined to transform religion, philosophy, art, music, science, language and sociology. Well may the Germans call its founder "der Einzige."

The connecting link between ancient and modern civilization during this transition period was found in the church. Early in its history the church had developed the institution of monasticism in the attempt to check the flagrant social evils of the east and preserve the purity of the northern races. The institution so established soon spread over all Europe, one order alone, the Benedictines, having at one time over 40,000 monasteries. The spirit of brotherhood thus manifested by the church was also apparent in the state in the development of feudalism from slavery, and more especially in the principle of chivalry.

The church, however, had a more direct influence upon culture by reason of the schools which sprang up in the shelter of the monasteries, and later developed into the early medieval universities. All learning, and particularly mathematics, was confined to these conventual schools, and comprised practically nothing more than was essential to the church. Learning was divided into the trivium and quadrivium, the trivium consisting of grammar, logic and rhetoric, or, in short, the mastery of the Latin language in which the services of the church were conducted, and the quadrivium consisting of arithmetic, music, geometry and astronomy. The latter were also limited to the needs of the church, comprising arithmetic for keeping accounts, music for use in church services, geometry for surveying the extensive property of the church, and astronomy for the calculation of Easter. These constituted the seven liberal arts, as enumerated in the line

lingua, tropus, ratio; numerus, tonus, angulus, astra,

and marked the limit of attainment, or, as expressed in a verse of the eleventh century,

Qui tria, qui septem, qui totum scibile novit.

The most significant effect produced by the church upon culture, however, arose in a manner unintentional and unforeseen. The rapid growth of papal authority had led the church to undertake violent measures for its own aggrandizement, chief of which was the crusades.

The activity incident to these great movements made Florence and Venice renowned for their wealth, while it also gave the Hanseatic League command of the trade of the north. With the growth of prosperity came increased leisure for intellectual development, resulting in the Italian Renaissance and the European Revival of Learning. The crusades also influenced development still more directly by opening lines of communication with the east, whereby the learning that had lain dormant in the Byzantine empire became current in Europe.

Toward the close of the fifteenth century the discovery of America, closely followed by the circumnavigation of the world, gave dominance once more to the influence of the sea. The effect of such a strong suggestion of boundless and unknown possibilities, intensified by the element of hazard and daring, became at once an important factor in development, stimulating ambition, creating moral fiber and inspiring a passion for freedom. With the opening of the sixteenth century the narrow and vague ideas characteristic of scholasticism began to give place to clear and strong thinking. As the church had been the center and source of medieval authority, the struggle for freedom naturally centered around this institution. Beginning with the reform of certain abuses, the spirit of the reformation ended by repudiating the entire authority of the church, epitomized by the action of Luther in nailing his ninety-five theses to the door of the church in Wittemberg, thus undermining the whole system of tradition and inaugurating a new principle of action based on individuality.

The relation of this mental attitude to the development of culture was nowhere more evident than in the trend taken by mathematics. Everywhere old methods were questioned and new ones substituted. The first great advance naturally occurred in Germany and Italy. In the former the time-honored system of Ptolemaic astronomy gave place to the Copernican theory, and notable advances were also made in other branches of mathematics, especially algebra and trigonometry. The intervention of the Thirty Years' War, followed by the Prussian war, stayed German development for a time, but with the return of peace the German spirit again manifested itself in the critical attitude toward science and religion which found expression in mathematics in the function theory, and in philosophy and religion in agnosticism.

In France where the invigorating effects of climate and race were less marked, the sixteenth century was characterized by such acts of religious intolerance as the massacres of Vassy and St. Bartholomew, leaving no energy for scientific pursuits. The ascension of Henry IV. to the throne, however, followed by the Edict of Nantes which terminated the religious strife, produced an immediate effect, the Age of Richelieu being remarkable for scientific and cultural progress. Great literature was produced and in mathematics the period was made illus-

trious by the names of Roberval, Descartes, Desargues, Fermat and Pascal, who in brief founded modern analytic and projective geometry, and laid the foundations for the calculus.

The latitude of England made it later in development than either France or Germany, while its insular position also introduced an important modification. Extensive commercial relations were developed, which, as in the case of the Phœnicians, forced arithmetic into prominence. The first advance consisted in substituting for the old Boethian arithmetic, inherited from the Romans, the more powerful algorism of the Arabs, introduced by way of the trade routes between England and Italy. In the hands of the English, however, arithmetic was soon transformed into the practical art demanded by their commerce and characteristic of their genius, the most notable addition being the invention of logarithms. So rapidly was this transformation effected that within a decade after the invention of logarithms they had come into general use.

With the growing mastery of man over nature the effect of environment in modifying history becomes somewhat less apparent. Sufficient has been said, however, to suggest the dynamic influence of geography upon culture, and indicate the new light thrown upon intellectual development when studied from the standpoint of physiography.

THE SCIENTIFIC PRESENTATION OF HISTORY

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THE question, "Is history a science or can it become a science?" has long both fascinated and irritated historical students. A few think that they have already discovered a science of history, but in reality have made only a premature and primarily speculative attempt at a philosophy of history. Some would limit their ideal to indiscriminate verification of the greatest possible number of "facts" and to indiscriminate exposure of the greatest possible number of historical fictions—sometimes adding the hard requirement of setting forth their unsystematic results in attractive literary form. Some are pessimistic because the historian can not perform experiments in the past and because even his observation is seriously limited by the scantiness of the material at his disposal. This is true, but of course does not exempt the historian from dealing with the data he does have in a scientific spirit. It only renders it the more imperative. Others more hopefully point to the progress made in modern times in the publication and criticism of sources as a sign of history's conversion to scientific method. But of scientific method in the process by which the sources are transformed into history and presented to the public one hears little. On the contrary, one finds prominent writers on historical method not merely admitting but almost rejoicing in, the impossibility of fixed principles of research, of scientific exposition of results.

Bernheim, in his "Lehrbuch der historischen Methode," after designating history as "Wissenschaft" and describing its purpose as not esthetic but informing, in proceeding to speak of the process of converting the sources into history draws all his similes from the fine arts. History is like a pianoforte rendition of an orchestral performance; it should, like a painting, make use of perspective; in it, as in a drama, the characters should be silent part of the time; gaps to fill in as between the scenes of a play should be left to the reader's imagination. In short, the turning out of the finished product is a fine art according to Bernheim, despite his denial. He says that it ought not to be poetry, but implies that it must be prose. His model historian's aim is to present the past vividly, not necessarily to prove anything. He should give specific bits from the sources occasionally, but more in order to make a story realistic than to make an exposition scientific. This story should follow either chronology or geography or "the logic of events."

It should emphasize some "facts" as essential, treat others as subordinate, omit others entirely. The only standard in this process of selection and discrimination, the sole guide in finding what the logic of events may be, seems to be the source material itself which Bernheim expects will suggest modes of treating the "facts" derived from it. These vague and inadequate recommendations as to method in historical writing at least show Bernheim's ideal of history to be not a detailed and systematic investigation of the past by analysis and classification but a well-proportioned narrative bringing events, characters and conditions vividly before the reader. Indeed he goes so far as to say, "Die litterarische Form der Darstellung welche man wählt, in entsprechender Weise die Auswahl des Mitzuteilenden bestimmt."[1]

Justin Winsor, writing in 1890 in *The Atlantic Monthly* on "The Perils of Historical Narrative,"[2] affirms distinctly that history's proper method is epic and that connected action should be its exclusive theme. He wants no "maundering method"; he desires with Milton an absence of "frequent interspersions of sentiment or a prolix dissertation on transactions which interrupt the series of events"; he demands "training and large familiarity," but instead of scientific presentation is content with a "story that travels steadily to the end." "To tell the story with Herodotus," he says, "is what we have come to, after all experimenting." In the writer of history Winsor thinks desirable the same faculties that make for the merchant his fortune, by which is probably meant a sort of snap judgment. Indeed we presently hear of the historian's divination. Moreover, the historian's personality and environment are sure to affect his work. "The interlacing of the ages makes the new telling of old stories a part of the intellectual development of the race and this retelling is necessarily subject to the writer's personality and to the influence upon him of his day and generation." But Winsor does not draw the conclusion that in an age of science history too should attain to scientific form.

M. Gabriel Monod, in two recent articles in *La Revue Bleue* on "La Méthode en Histoire" writes in much the same vein.[3] For him again the historian seems to be the spinner of one connected story and rather more of an artist than scientist. He "reconstructs in his brain the image of the past."[4] Again we hear of the essential facts, of others merely accessory to these, of still others to be omitted entirely from the history, though all should be present in the historian's thought to influence his selection or to aid his constructive imagination in bridging the gaps in the sources by logical inference. Monod, however, believes that the historian can not only pick out the nuggets of "essential

[1] Bernheim, "Lehrbuch der Historischen Methode," Leipzig, 1903, p. 724.

[2] Volume 66, pp. 289 et seq. The quotations which follow in the text occur on pp. 292–294.

[3] Fifth Series, Vol. IX., April 11 and 18, 1908.

[4] *Ibid.*, p. 487.

fact" from the chaos of ore before him, but also mint the coin of general truths.[5] Indeed he is hopeful of deriving a sound generalization even from a mass of particular facts some of which are doubtful. He recognizes further that to accomplish this is no simple matter, as when, for instance, he says that the evaluation of the relative worth of the facts is a problem "délicate et sujette à mille causes d'erreurs." But it is also in his opinion a problem where "rules are insufficient" and where individual genius is called for, where sometimes "even a sort of intuition penetrates further than study and reflection."[6]

That is that divination of which Winsor spoke—a feeling-it-in-one's bones method. History written thus would be more like a feat of magic than the work of science. To identify historian and magician is of course absurd, yet it must be said that a certain mystery enveloping the labors of the historian lends further color to the fancy. The historian has too much the air of entering a holy of holies of the sources where none but he dare tread and whence he will in due time emerge bearing precious secrets from beyond the veil. Rather cabbalistic footnotes make the mystery the more esoteric. He judges the past not in open court with the evidence made public, the press admitted, a jury hearing all the facts and then rendering its verdict, but in secret inquisition where he alone is both advocate and judge—and sometimes torturer. Another historian may retry the case if he wish, but will need to start again almost from the beginning. So sixteenth century mathematicians published their new formulæ but kept from the world the processes by which they had been attained. Only there is the difference that those formulæ justified themselves in use; the historian's results must be taken entirely on faith. Of course the conscientious historian of to-day has no desire to cover his tracks, he makes by bibliography and references an endeavor to indicate them to the reader, but he seems to despair of a complete scientific exposition of his labors. Yet even if he can not always hit the truth, even if history has no scientific laws, surely his thought about history can give an account of itself. Surely, too, its methods must be ones of which it can give an account.

Monod, to do him justice, to some extent realizes the former possibility if not the latter requirement. He finally gives three "general rules" of historical presentation. First, the sources used by the historian should be indicated; second, proof of his statements should be furnished as far as possible; third, he should sharply distinguish those points of which he feels sure from those which are more or less uncertain. These rules, vague in their wording and inadequate in their scope, are a faithful reflection of the present unsatisfactory and indefinite status of historical presentation. "Indicate" the sources:—

[5] The metaphor is mine, not Monod's.

[6] *Ibid.*, p. 489.

what does that mean; how far should such indication go? "Furnish proof":—how is it to be got in order to be furnished? What constitutes proof? "As far as possible":—surely a weak-kneed and half-hearted phrase, but probably meant to leave way for the undemonstrable results of intuition and divination. As for the third rule:—how shall he make the sharp distinction, and further, ought he not rather to supply that which will make his readers certain or uncertain than merely to state his own convictions and doubts. Professor James Harvey Robinson writes on this point, "The historian has no accurate means of representing his own dubiety, strongly as he may be conscious of it. Much less can he impart his doubts and uncertainties to his reader"[7] since history "possesses no special terminology adapted to its specific uses and historical writers content themselves with vague and uncertain expressions which are in their nature literary rather than scientific."[8] Robinson, it should be said, both in the article just cited and in a lecture on "History" published in 1908 by the Columbia University Press, makes several incidental suggestions stimulating to one interested in scientific presentation, although his main aim is to expose the defects of the literary method of presenting history and he does not go on to attempt a theory of scientific presentation.

The most recent noteworthy instance of discouragement of endeavor to present history scientifically was the last annual address by a president of the American Historical Association. Professor George Burton Adams did not, like Bernheim and Winsor, disregard the possibility of scientific history; he clearly put the question, "In ascertaining and classifying the objective facts with which history deals can methods which are really scientific be employed . . ."?[9] But he went on to say coolly, "History must remain one of the branches of literature"—a servitude incompatible with scientific status. Then a little later, when wisely discouraging present attempts to philosophize history, he tended towards the opposite extreme and declared that, "The field of the historian is and must long remain the discovery and recording of what actually happened,"[10]—thereby abandoning Monod's hope of attaining to general truths and taking up a position not much more consoling to scientist than to philosopher.

On the other hand, there are tendencies toward scientific presentation outside the pages of writers on historical method. Even those who would incontinently discover some one hypothesis—for instance, the economic interpretation of history—to charm the "facts" of history from a chaos into a system, have at least invoked the name of science.

[7] "The Conception and Methods of History." Congress of Arts and Science, Universal Exposition, St. Louis, 1904. Vol. II., p. 46.

[8] *Ibid.*, p. 41.

[9] "History and the Philosophy of History," *American Historical Review*, January, 1909, p. 232.

[10] *Ibid.*, p. 236.

True, these makers of hypotheses may be in too great haste to reach their goal and base their results on dubious and insufficient data rather than undertake a thorough examination of the source material. They may resemble the Ionian philosophers with their single world grounds rather than the slow, painstaking observers and experimenters of modern science. But, like the Greek sages, those who would conquer history at a blow have not led their forlorn hope quite in vain. However faulty their execution, they have at least corrected the assumption of Bernheim and Winsor that history is merely something to narrate and have held it to be something to study, to classify, to evaluate.

Nor does present orthodox historical practise lag behind with historical theory as sketched above. Original research of to-day would generally scorn intuitive methods, and the presentation of the results of such research is seldom primarily literary. But unfortunately, since the methods of research employed are seldom fully exposed, even if we take their validity for granted so far as the particular results are concerned, we are still left without the needed data for a theory of scientific presentation. No common and accepted methods have been formulated. Moreover, while such preliminary work as the editing of the sources is painstaking and while original research is done more or less scientifically, there is a marked tendency to limit the sphere of scientific investigation to the bare "facts," to "what actually happened"—to use Adams's phrase—and to look at least for the present upon further analysis and synthesis, upon the composition of history for the public, upon the manufacture of the final product, as an art either not needing or not permitting regulation, and as sufficiently scientific if it employs the results of the two earlier processes, no matter how it may use them. Thus is built on rock a house of sand. But that is not all. The flimsy superstructure is two-storied, for there are no bare "facts" of history.

The first step towards a correct theory of scientific investigation and presentation is then to show that there are no separate and particular objective facts of history; that consequently investigation having them as its object must be fruitless; and that methods of writing history based—as were all those which have been outlined—upon the assumption that they exist are wrong. When this is done, we shall be in a position to see much better what is the task of historical investigation and hence what is its fitting method. Only when we understand that "ascertaining and classifying objective facts" is not history's true business, may we with hope of success put the question, "Can methods which are really scientific be employed?"

What then are meant by the "facts" of history? Is there in the field of history any such definite and fundamental unit as the cell in biology? Are facts indivisible, elemental entities, found hanging ripe as it were on the branches of the sources and needing only to be plucked and picked over according to their essentiality and then to be canned in works of particular research until the day when all fruit shall have

been gathered and shall be crushed together to make one surpassing syrup—the philosophy of history? No; as yet no historical units have been discovered. The word "fact" is, like the word "event," merely a convenient but exceedingly indefinite term. A fact is any fragment of historic truth just as an event is an arbitrary division of the past. To speak of "objective facts" of history then is impermissible. How much a fact or an event shall include is an entirely subjective matter. A war is a fact or event, so is any battle in it, so is the death of any soldier in the battle.

Qualitatively a fact or an event is quite as difficult to limit. Bernheim and Winsor displayed a tendency to restrict the "facts" of history to epic material and Adams seems at first sight to give the same thought its most recent expression in saying, "The field of the historian is and must long remain the discovery and recording of what actually happened." But it is idle to try to study "past action" by itself. We must know the *milieu,* the material, social and intellectual environment in which an event happened, in order properly to understand the event. But why single out "events" for our attention? Why not study the past without qualification? And again, what are "events"? Every external act had its inner concomitant, cause or result. Science and art have their "connected action," as well as states and dynasties. The very conditions which form the *milieu* for some act are themselves really in constant flux and so "happening" from day to day. In the last analysis, therefore, "what actually happened," like "facts," is no other limitation upon the scope of history than the negative one of excluding fictions and philosophizing. Truth and unvarnished truth are all they mean. Everything in the past is still left as the province of history.

There is, however, another possible explanation of the expression "the facts of history." One might narrow the definition of history by accepting roughly the limited scope of past historians and trying to discover only "facts" of the sort which they give. Of course, exactly to define what sorts of past phenomena they recorded would be difficult but it is also not easy apparently for modern investigators to strike out along new lines. The tradition though vague is powerful. Herodotus and his successors too often not merely—witness Winsor—suggest to moderns their method, but also their matter. Yet if history were narrowed down from its possible scope as investigation of the past in the interest of and with especial reference to man to a study of only the writings of those men in the past who were called historians, it evidently would become mere scholasticism, a barren commentary upon traditional authorities. It is only less unsatisfactory to confine history to material additional to but similar to that with which they dealt. Their standards can be bettered, not merely as they have been by the modern attitude to sources and the modern historical sense, but also in point of the content of history and the mode of presenting it. The historian to-day must not impose on the public the limited round of topics which

satisfied Greek warriors or medieval monks. He must tell us what we wish to know and also what we need to know; he must write not merely for his readers, but for science.

Within history itself there may be boundaries mapping it off into departments, as political history, the history of literature, the history of philosophy. But these very names imply that beyond them there is a broader science, history, investigating the past in its entirety so far as it concerns man. Whatever in the past influenced human life appreciably then, or has significance for human life of the present day, may well be included in the science of history, or in some great science. The historian's task, writes Robinson, "is nothing less than the synthesis of the results of special sciences."[11] Moreover, it is something more than this. The architect, for example, studies the history of architecture for the sake of his art of building; the historian includes the past of architecture in his study because of its relation to human life and progress. While, therefore, the technical researches in such partial fields as the past of architecture, of literature or of philosophy may be of great assistance to the historian, he can not content himself with compiling their results, for the reason that their technical interests are different from his broader aim. He must refashion and interpret their results before they will be available for his purpose and he must do original work of his own.

Returning to consideration of the phrases, "the facts of history" and "what actually happened," it is to be noted that they may further involve a stricture as to method. Their implication is that the investigator must occupy himself for the present with the content of history, with phenomena; that the time has not yet come for discovering its form, that is, laws and general truths. This is perhaps the fairer way to interpret Adams's utterance, and there is prudence in the attitude. The beginnings of the science of history must be cautious; science must not be impatient and race after irresponsible speculation and theorizing. It also must not be backward and rest content with aimless empiricism. It is true, as Adams says, that we must have foundations before we can build; but we must lay them with a view to building. A fact we have seen to be a vague and arbitrary division since in history's continuity and complexity no particulars having reality have yet been discovered. Consequently for investigators merely to cut out "facts" from the sources and store them up for future study is unlikely to lead to much progress, since there is no significance in the detached parts and since it will scarcely be possible to fit them together again into anything except the original chaos from which they were cut. "Facts," then, will not do as an intermediate stage in historic research any more than as a final goal. There must be something to give form to research. A more purposeful and direct method will be to

[11] "The Conception and Methods of History," p. 51.

seek to demonstrate scientific propositions immediately from the sources. Surely we have questions to put to the past, problems whose solution will be of scientific value far beyond any epic recital. Anything approaching a complete philosophy of history is and long will be out of the question, but none the less we may even now deal in a small and humble and tentative way with generalizations and hypotheses, provided we never make them except to test them by the source material at our disposal and by rigorous scientific methods, and make them only of such extent as our original investigation can compass.

There is another reason why the historical investigator must take the initiative and address inquiries to the source material rather than count upon it for indication of "the logic of events" or for other direction and guidance. It is the scantiness and fragmentary character of the source material. If we had fairly complete records we might from a mere reading of them, from mere "study and reflection"—to use Monod's phrase—get a fairly complete picture, provided the mind could comprehend and digest so great a mass of data. But with things as they are a different method than that of mere open-mindedness and absorption is practically forced upon us. Hypothesis and analysis are called for. The fragments by themselves often suggest little or nothing; it is, at least as yet, impossible to reconstruct from them the original complex whole; it accordingly remains to take up point after point which we wish to know about man and the world and see how far the fragments will contribute to the solution of these simpler and partial problems. This is not to say that we shall take no hints from the source material as to the themes of our investigation. Where the fragments suggest some generalization, some hypothesis of value, the historian may well follow it up; where they do not, let him be the aggressor.

With such the aim of historical investigation, what shall be its method? Is present historical presentation adequate to portray this method? If not, what will be the new scientific presentation that will effect this? These are the questions that remain to be considered.

Since the historian is to ask definite questions of the past instead of indiscriminately collecting "facts," his method both in investigation and presentation will gain greatly in definiteness and unity. He will know what source material is essential and what not, since his inquiry furnishes a standard; Bernheim's historian had only the source material to tell him what source material was essential. The historian will not be at a loss for a plan by which he may conduct his investigation and order the presentation of his work, since he has a definite subject and also a definite method—to prove or to disprove. He will not be left to grapple with a theme as it may chance to present itself, to discover this or that phase or fragment, and to present these discoveries to his readers according to any plan that hits his fancy. He will

escape that frequent failing of German scholarship—the squandering of Herculean labor in the compilation of specific details, "facts," in other words, upon an inadequate conception of the general bearings of the subject. There comes to mind a "standard" work upon the humanism of the Renaissance, a book cited among the best in bibliographies. It consists almost entirely of a series of little essays on various humanists, containing very miscellaneous information and tacked together by artificial literary transitions. One might take a large sheet of paper, write the names of the humanists in a vertical column, set against these in succeeding columns such points as date of birth and death, parentage, patrons, pupils, chief writings, purity of Latinity, knowledge of Greek, religious attitude, and have before one not merely the whole volume but more, since now one would be in a better position to grasp the subject as a whole and see to some slight extent how individuals worked together to make a movement

The scientific historian will see not only that his theme must be developed systematically, but also that every concept which may be implicated in his investigation must be sharply defined and henceforth consistently treated from that one point of view. The field must be fenced in, if any truth is to be corralled. If one is trying to bring out characteristics of a given period of time, evidently one must limit oneself to it. If a "movement" or an institution is concerned, it should be as exactly defined as possible in terms of those phenomena, qualities, and tendencies which are peculiar to it. Thus its gradual beginning, height and fading may be adequately recognized and discriminated from each other and from events contemporary but unconnected with either. Indeed, the historian who has denied the existence of "facts" will be inclined to look askance also at periods, movements and institutions. He will shake himself free from unjustifiable historical conglomerates as well as from false historical units. We shall get from his pen no dreary historical miscellanies, no omnibus biographies. He will be trying to prove something and will assume nothing.

While then the scientific historian will sharply define every concept and field, he will not make the mistake of thinking that some portion of the historical field can be fenced off and studied by itself, as investigators of periods and places too often do now. In history's continuity and complexity not only have particulars no reality, but generalizations have no truth unless followed through the whole stream. They may take on a different significance when brought into contact with other truths. Historical measurements have relative rather than absolute value. They must be in more than one dimension. Is this asking too much? Must the historical investigator know everything before he can find out anything? Not if he does not attempt to discover too much or to measure that which has too many relations—as does a period. Not if he takes a problem sufficiently precise and limited to be covered, as it should be, by considering everything that is likely to have any

relation to it. This is the direction in which original research has been tending but has not wholly attained, owing to its attachment to the false conceptions of historical "facts" and groups of facts, and to its dependence upon the source material for form as well as for matter.

In short, the historian should take the measure of everything he has to deal with, just as the scientist takes into account every factor affecting his experiment. That he can not measure as accurately and completely as the chemist or the physicist is the very worst reason for his not measuring at all. If periods, movements and human motives are so uncertain—as historians sometimes tell us by way of excuse—how can one venture to assume them instead of trying to remove to some extent that uncertainty or of frankly recording it as an element of error in the investigation? Much could be measured that never has been. While some of the researches in which historians are engaged give no promise of sure results and offer rather a broad choice of plausible or ingenious theories, extensive past literatures teeming with human prejudices, motives and ideas are waiting for accurate measurement and estimation. Were extant Greek literature, for instance, sifted thoroughly and its utterances on different topics collated and evaluated, many existing notions about Greek civilization might be modified, many new truths about it and its relations to the culture of other periods might be revealed. Or at least we should gain firm ground to stand on. For while classical scholarship is intent on minute points of ancient customs and language, for ancient ideas we have no statistics, only opinions. Such opinions have been formed no doubt as a result of acquaintance with the source material, but that fact alone is not enough. Science is not satisfied by a sort of alchemistic process in which various ingredients of source material are thrown by the historian into the seething kettle of his intellect, whence, after long subjection to the fires of unconscious cerebration and the juices of ripe reflection, they are supposed to emerge fused and transmuted into historical truth. There must be a complete and accurate analysis and measurement of that material and a sound process of deducing historical truth therefrom. This may be illustrated in more detail.

The necessity of qualitative measurement of statements not only *per se,* but with reference to the sources from which they are drawn, is generally recognized; but historians as yet seldom heed the twin requirement of quantitative measurement of our data in comparison with the sources whence they come. It is well understood that one must take into account the reliability of the source from which the statement comes, the circumstances under which it was written, the attitude of its author—whether superstitious or sceptical, rhetorical or sober, gossipy or official, spiteful or eulogistic, contemporary or hearsay, doctrinaire or unconscious and objective. On the other hand, while the scarcity of source material is often noticed, the amount of relevant material is seldom discounted to affect the worth of a particular point supported by

specific statement in the sources. Yet a point is not proved by two or three bits of favorable evidence if the available sources are such that ten or twelve confirmations might be expected. Or the available source material may be so scanty that it does not offer sufficient basis for any positive conclusions. One should try to determine not only how much evidence there is on the point in question and in what degree it bears upon that point, but also how much there ought to be. The quantity of evidence pro and con must be measured not only absolutely, but also in proportion to the available source material, and further with regard to the source material which is missing.

After adopting and working out in full detail through practise the method of research which has here been but suggested, historians will still have the duty of showing others, not only their results but the solid foundations on which these rest and the process by which they were attained. This obligation is recognized to-day to the extent that a historical work without bibliography, footnotes or references to the sources is not considered scholarly. But this is not enough. A list of the books that the historian has used is far from fulfilling the requirement which science makes of a complete analysis of the source material. It gives little idea of the character, scope, applicability and reliability of the source material, even though some word of comment be attached to each title. Fault may be found, moreover, with the footnote as a means of proof. And here is criticized the footnote at its best, rather than when, with pretentiously long quotations in foreign tongues and with superfluity of scholarly digression and learned small talk, it degenerates from a pillar by which science supports its results into a pedestal upon which erudition poses; or when, instead of bearing upon the main point, it gives specific references merely for some accompanying illustrative detail which proves nothing. At its best the footnote less actually proves a point than furnishes indications how one can set about proving it for oneself. Then, owing to the erroneous notion about "facts" of history, each footnote attaches itself to some one point in the text. Thus all the notes taken together supply means for verifying particular statements, but do not substantiate general truths nor lead us to scientific propositions. That must be done in the text, if at all. But here is a third disadvantage that the proof contained in the notes, besides being subdivided there and so losing the strength of union, is further detached from the proof in the text. Yet the very existence of the footnote bears witness that the literary method of presentation at present employed in the text is unsatisfactory for scientific purposes, testifying that the whole would become even clumsier and more confused were the attempt made to embody the notes in the text.

The remedy is a presentation primarily scientific, a unified and uninterrupted presentation of the complete historical process from raw material to finished product. The historian will reveal his investigations as well as their results. After stating and defining his problem

with scientific exactness, he will make perfectly clear the material available and utilized for the solution of the problem, and will inform us of the plan by which that material will be exploited. Then will follow naturally the subjection of that material to these methods and the consequent results, positive or negative, partial or complete. Presentation will follow investigation step by step.

Moreover, since investigation will be so completely a matter of accurate measurement and of accurate conclusion therefrom, the method of presentation will probably somewhat resemble that employed by mathematics and the sciences. We shall come, not merely to the historical terminology which Robinson desires, but also to standards of historical measurement, modes of historical reckoning, historical symbols, curves, charts and other graphic means of presenting briefly and accurately what prose could compass only in many pages or fail to express with requisite precision and discrimination. Thus, while historians will present proof as well as results, this greater detail than is at present given will be so put that it can be looked over in less time. Historians will no longer be handicapped as were the medieval algebraists who wrote out their equations in words. Other sciences of human life, psychology, economics, sociology, have already turned to such methods; history alone remains backward and awkward. Yet the scantiness of the material at its disposal, in comparison with the abundant opportunity for experiment and observation possessed by the others, requires from it even more accurate inspection, calculus and presentation.

Even in historical manuals, text-books, general treatments of countries and ages, and other works of too pretentious scope and abbreviated form to be based directly on the source material and use of scientific processes, there will be no reason why scientific propositions may not in increasing measure constitute the contents, the field be definite, the form in accord with the true spirit of history. Possibly fewer persons would study the reformed presentation than read histories at present, but they would learn more truth of value, gain a deeper insight into the true nature of history, and have a greater respect for it. One could not then dismiss it as "a branch of literature." Its utterances would rest neither on vague consensus of opinion, nor on the reputation, nor on the footnotes of this and that individual; but upon a common method, open to the scrutiny of all and worked out in its fullness by generations of scholars, though applied in each particular investigation by an individual mind.

THE NATURE OF FATIGUE[1]

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TO the conscientious schoolmaster the contemplation of a dissertation on the nature of fatigue can hardly seem an unmixed joy; for the subject is one with which he is already practically and sadly familiar. I may say at once, however, that I have not come here to remind you too acutely of this aspect of your professional work, your sensations at the end of a busy day in the class room. I, too, have felt those sensations, and I know how dully depressing, to both mind and body, they may be. They must be reckoned with and eliminated in the reform of the school. Much is written on the fatigue of the school child, but the ideal school course will allow the teacher too to bring an unjaded spirit to his successive tasks. In his Utopia the teacher will have his playground, as the child now has his. My present task, however, is not to limit myself to a discussion of the fatigue that is incident to life in the schoolroom, but to present to you a study of a specific topic in physiology, and to try to show that it has broad biological bearings.

In popular usage the term fatigue is employed loosely, for while it signifies, in general, a depression of physiological activity, resulting strictly from previous activity, physiological depression is often called fatigue when it is not at all clear that previous activity is at the bottom of it. It does not, however, appear to me at present necessary to hold always to the strict significance of the word, since in a given case there are still too many unknown causative factors. Moreover, in the marvelously complex weft of the human organism, where the physical and the psychical are inextricably intermingled, illusion is so readily mistaken for reality, especially in the phenomenon now before us, as often to make the detection of a genuine fatigue well-nigh impossible.

Let me proceed at once to an analysis of the phenomenon of fatigue. Every one is familiar with its sensations; but not every one realizes that the sensations are but signs of physical and chemical conditions permeating the whole body. Fatigue is a general physiological phenomenon; not only is the whole body subject to it, but every organ, tissue and cell of which the body is composed. Like other general physiological phenomena, its study may be best approached by considering its manifestations in the parts of the organism. I propose to

[1] An address delivered before the Section on Hygiene of the Connecticut State Teachers' Association, at New Haven and Hartford, October 22, 1909.

examine it first in the tissue of voluntary muscle, which affords certain advantages for study over other tissues, because of the ease of employing the graphic method and other physical, as well as chemical, methods.

If, shortly after the death of an animal, a single muscle, such as a muscle of a leg, be removed from the body, be attached to the usual muscle lever of the physiological laboratory, and be stimulated in the usual manner at regular intervals, beginning when the muscle is fresh and continuing until it is well fatigued, the graphic record of the

FIG. 1. Series of contractions of a frog's sartorius muscle, excised and stimulated at intervals of two and one half seconds. Each successive vertical line is the record of a single contraction. The contractions at first increase in extent, this stage constituting the treppe, and later decrease, this stage constituting fatigue.

series of resulting contractions presents a striking picture. Both the extent and the duration of the contractions may be affected. There appears early an increase in the extent of the contractions, which proceeds gradually to a maximum. This is shown in the graphic record as an increase in the height of the successive muscle curves (Fig. 1) and has been called, not inappropriately, the staircase, or *treppe*. The treppe signifies that in the early stages of muscular activity the working power of the muscle is progressively augmented—there is a temporary improvement in the power to work. This in turn means that what physiologists call the irritability of the muscle, or, in other words, its power of responding to a stimulus, has become greater; hence the same stimulus is followed by a greater contraction. A progressive improvement in the power to work in the early portion of a task, I may say, is not peculiar to muscle. We all must have noticed it in our own experience, with both physical and mental labor. It has also been demonstrated by laboratory methods in nerves, the central nervous system, and other animal and plant tissues; and it is probably a characteristic of all living substance. An analogous phenomenon is observed when living substance is put under the influence of certain drugs—a small quantity of alcohol, for example, often effects a temporary improvement in the individual's power of performing work.

Following the treppe, the muscle may perform maximal contractions for a considerable time; it is in its best working condition; its irritability is such that a given stimulus calls forth the greatest contraction of which it is capable. But sooner or later the contractions begin to diminish in extent; they sink to the level of the original amount and below it; the muscle becomes gradually weaker and weaker, until, with long-continued effort, it may finally cease altogether to lift the weight. This decrease in working power from the maximum characterizes the

stage of fatigue proper. Decrease in working power may, in fact, be said to be the universal physical phenomenon of fatigue, whatever form of protoplasm we may be considering. Decrease in working power is accompanied by a decrease in irritability. The stimulus remaining the same, the work is diminished; but if the stimulus be increased in intensity, the protoplasm may again perform more work for a brief time. Sooner or later, however, all stimuli cease to be effective, and the living substance is then either exhausted or dead.

FIG. 2. Series of contractions of the frog's gastrocnemius muscle, excised and stimulated at intervals of two seconds. Every fiftieth contraction is recorded. The increase in the duration of the process of relaxation as fatigue proceeds is shown in the progressive lengthening of the descending limb of the curves.

If, in our graphic record of muscular fatigue, we are employing a favorite subject of physiological study, the muscle of the frog, we observe another striking physical change. Early in the series, even before the treppe has reached its maximum, the duration of each contraction begins to increase, mainly by a slowing of the process of relaxation (Figs. 2 and 3). This may reach great proportions before exhaustion sets in. This slowing of relaxation appears to be wholly absent in the fatigue of warm-blooded, and presumably of human muscle (Fig. 4).

The fatigue of muscle tissue is thus characterized by marked physical peculiarities. It is only natural to ask what are the causes of these.

Happily it is becoming the fashion in physiology, if only slowly and following long after, it is true, the usage of John Stuart Mill, to speak less of causes than of conditions. The cause of a phenomenon is the sum total of its conditions. All conditions are causes, and it is illogical to select one or two conditions and dignify them by the seemingly superior designation. In speaking of the causes of fatigue, as is often done, one usually means its chemical conditions; for within protoplasm, when in activity, there occur certain chemical or metabolic changes, with which the phenomenon of fatigue is closely associated. These chemical changes involve two general processes, namely, the consumption of certain existing substances which are essential to the activity of the protoplasm, and the production and accumulation within it of certain waste substances. Here again the muscle has yielded us our chief knowledge. Of the substances that are consumed in protoplasmic activity, we know most about two, oxygen and carbohydrate. For all aerobic tissues or organisms a continual supply of oxygen is essential to the continuance of working power—in fact, one way of bringing on the main phenomena of fatigue seems to be by eliminating

oxygen. On the other hand, recent work suggests that one of the means of increasing working power or temporarily, at least, delaying its loss, is by artificially supplying oxygen to the body. It has been known for some time that with the usual conditions under which we live, the main source of the energy of muscles and probably of other organs is carbohydrate material, glycogen or its near

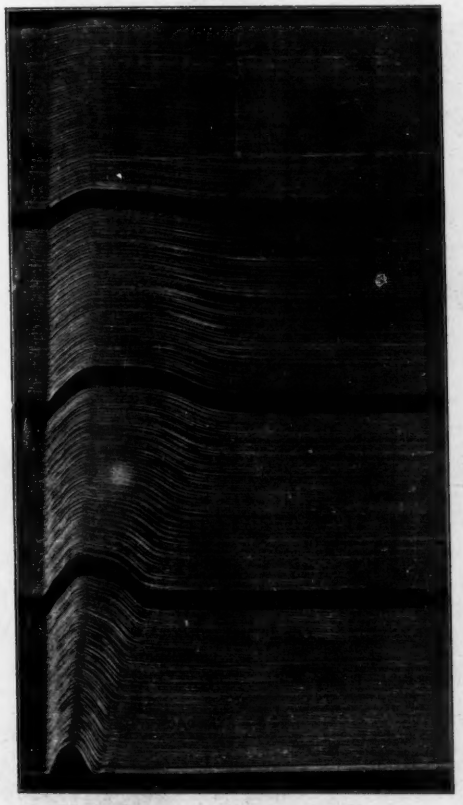

FIG. 3. Series of 550 contractions of a frog's gastrocnemius muscle, excised and stimulated at intervals of two seconds. Every contraction is recorded, except at the places indicated by the black bands, at each of which the records of fourteen contractions are omitted. The record of the first contraction is at the bottom of the figure: that of the last one at the top. Fatigue is shown in the progressive decrease in height and the increase in length of the curves.

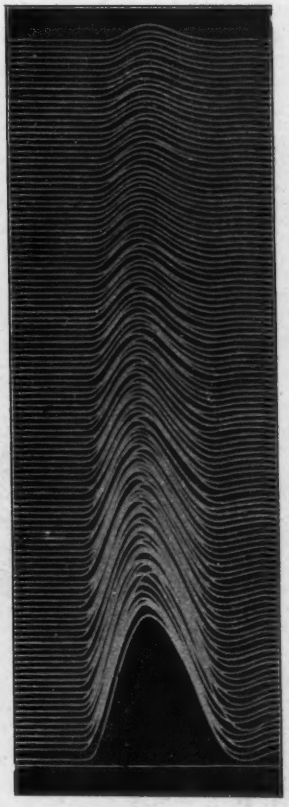

FIG. 4. Series of contractions of a rat's gastrocnemius muscle, excised and stimulated at intervals of two and one half seconds. Fatigue is shown in the progressive decrease in height of the curves.

relative, sugar. In the burning of carbohydrate in the tissues its potential energy becomes the actual energy of heat and muscle work. This fact would suggest the loss of carbohydrate as one of the factors in the oncoming of fatigue, especially in its later stages. Exact laboratory investigation, moreover, shows that if most of the carbohydrate be removed from an animal's body, he presents the symptoms of pro-

nounced fatigue; and the same is true of his individual muscles, which are incapable of performing as many contractions as the muscles of a normal animal. Feeding such an animal with sugar restores his energy and makes his muscles capable of greater labor. This latter experiment has its counterpart in the common practise, by soldiers, guides and explorers, of consuming sweets, such as maple sugar, chocolate and raisins, when on long marches; while for the farmer in the hayfield nothing is more gratifying than a sweetened drink. It is quite possible that future research will discover other substances, besides oxygen and carbohydrate, the loss of which to the tissues is conducive to the production of fatigue.

Oxidation and destruction of carbohydrate result in the formation of at least two waste substances, both of an acid character, namely, carbon dioxide and lactic acid. Now it is an interesting fact, derived from laboratory investigation, that both of these substances, when in any but small quantity, are inimical to protoplasmic activity, and, furthermore, that a muscle under their influence shows the very same physical symptoms that are shown by a muscle fatigued through work. A fresh muscle to which has been given a moderate or considerable quantity of either one of these substances is a muscle already fatigued, although it may have performed no work (Fig. 5). These two metabolic products are thus believed to be important factors in the causation of fatigue, and to them has been given the name, "fatigue substances." Fatigue substances are poisonous, or toxic, to protoplasm; they diminish its irritability, so that a given stimulus calls out a less response than before. Certain other substances, besides carbon dioxide and lactic acid, are thought to belong to the class of fatigue substances, some of which are probably produced normally, while others occur only in diseased conditions. Among these pathological fatigue substances may be mentioned β-oxybutyric acid, which is present often in large quantities in a body suffering from diabetes—and it is a well-known fact that a person afflicted with diabetes is incapable of any considerable labor without extreme fatigue. β-oxybutyric acid occurs also in a starving body. The weakness of a person in starvation is associated

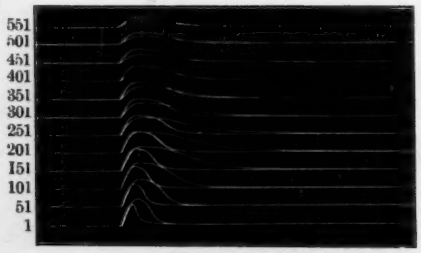

FIG. 5. Series of contractions of the two gastrocnemius muscles of a frog, excised and stimulated at intervals of two seconds; the one muscle normal, the other under the influence of carbon dioxide. The longer, or, in the later contractions, the lower curves are those of the poisoned muscle. Every fiftieth contraction of the two muscles is recorded from the same base line. The augmenting action of the fatigue substance is visible in the first two hundred contractions; its fatiguing action in the subsequent ones.

partly with the absence of the essential carbohydrate or other food stuff, and partly with the presence of β-oxybutyric acid. It is probable that future research will add still others to the class of fatigue substances, especially to those which are accompaniments of disease. Fatigue is one of the most common features of disease, and especially of diseases that are characterized by an upset of the chemical balance of the body. In such cases a considerable increase in the quantity of some intermediate metabolic product may conceivably lead to fatigue phenomena.

A few years ago, in studying experimentally the action of fatigue substances on muscle, I came upon an unexpected result. Fatigue substances in small quantity have a physiological action which is exactly the reverse of that of the same substances in larger quantity—instead of depressing or fatiguing protoplasm, they act so as to augment its activity. In other words, they increase its irritability, so that a given stimulus is capable of eliciting a greater response than it could elicit without the aid of the fatigue substances. Graphic records of the contractions of muscles under the influence of very small quantities of carbon dioxide, lactic acid or other fatigue substances, show how potent this augmenting action may be (Fig. 5). I believe that in this action we have the long-sought explanation of the treppe. In the early stages of muscular work the fatigue substances are present in small quantity, in later stages in large quantity. Correspondingly in the early stages there is augmentation or treppe; in the later stages there is depression or fatigue.

Thus far I have confined myself largely to a consideration of fatigue as exhibited by muscles, where the phenomena are best known and can be studied most accurately. There is every reason to believe, however, that the main principles of muscular fatigue are demonstrable in the other tissues and organs of the body—that in them also fatigue is characterized, physically, by a diminution in working power and, chemically, by both the destruction of energy-yielding substances and the appearance of toxic metabolic products. Diminution of working power is manifested in very different ways by diverse tissues. Glands in fatigue seem to secrete less than when fresh, and it may be that the action of digestive juices is diminished. The kidneys may be deranged, so that their epithelium is unable wholly to prevent the passage of albumin from the blood to the urine. A fatigued heart is dilated, its beats are quickened and may become irregular, and its diastole, or resting period, may become abbreviated. Fatigue often results in an abnormally high bodily temperature, constituting a fatigue fever. The chemical phenomena of fatigue in the various organs and tissues, apart from the muscles, is almost wholly unstudied, and there is great need of a careful analysis of the entire subject.

The fatigue of the nervous system is of great general interest, yet

there are few subjects in experimental physiology that are more difficult of study. Notwithstanding that most of us doubtless believe that we know the symptoms of nervous fatigue well, physiologists have been able to discover only scraps of fact in this field. The isolated nerve of a cold-blooded animal, when artificially stimulated in the laboratory, can perform its work for many hours without showing the least sign of a diminution of power. Only when placed under unfavorable conditions, such as in light anesthesia, or when deprived of oxygen, does the nerve exhibit with continued stimulation a gradual loss of conductivity. From this it is inferred that the nerve fiber itself under normal circumstances is highly resistant to fatigue, and that any unfavorable dissimilative changes which it undergoes in activity are compensated for at once by an equal assimilation. This highly interesting and suggestive conclusion is perhaps equally true of nerve centers. Hodge and others, it is true, have demonstrated morphological changes in nerve cells as the result of artificial stimulation and of normal daily activity. Thus the nuclei of the brain cells of a honey bee may show a diminution in volume of 75 per cent., at the end of a day's labor; and the English sparrow, though popularly regarded as less typical of industry, reveals almost as much cerebral activity. Notwithstanding these evidences of metabolism, no one has yet succeeded in obtaining, by direct or reflex artificial stimulation of the nerve ganglia, the spinal cord or the brain of animals, indisputable physiological evidence of the genuine fatigue of the nerve structures involved. Many attempts have been made to detect fatigue in the nervous system by testing the muscular power, as by the employment of the ergograph, the instrument in which a muscle or set of muscles is made to perform a series of voluntary contractions and lift a given weight, the progress of fatigue being indicated by the rate at which the lift diminishes. But endeavors to arrive at an exact analysis of the result of such an apparently simple experiment have given rise to a controversy as to the location of the fatigue, some investigators claiming it for the muscles, others for the brain.

A still further attempt at the investigation of brain fatigue is through the study of certain mental processes during or following long-continued effort. Mental fatigue is characterized by a diminution of attention, a difficulty in concentrating one's thoughts, slowness in reacting to sensory stimuli, in memorizing or in reasoning, difficulty in recalling memorized passages, errors or slowness in mathematical calculations, and other phenomena. While these are obvious in the fatigued individual, all attempts at exact measurement of them and the deduction therefrom of the degree of psychical or physical fatigue have failed.

Thus, while some of the characteristics of nervous fatigue are known, all methods heretofore adopted to study the fatigue of the

central nervous system exactly with a view of determining its relative susceptibility to fatigue are unsatisfactory. The preponderance of evidence at present seems to me to be in favor of a high degree of resistance to fatigue on the part of the brain and spinal cord, as of the nerve fiber itself. In fact, such a condition is what we should expect *a priori*. The nervous system is the administrative instrument of the individual; it directs, controls and harmonizes the work of the parts of the organic machine, and gives unity to the whole. It is not the frail, delicate thing, easily put out of gear, that we at times believe it to be. It is capable of enormous demands on its powers and of enormous resistance. It is the last system to succumb in many diseases and in such a dire condition as starvation. It would seem to be only highly advantageous to the organism that its nervous system should be able to resist the oncoming of fatigue, with all the direful consequences that might follow its advent.

After thus analyzing the phenomena of fatigue in their manifestations in the various organs and tissues of a complex body, let us briefly consider fatigue as we feel it in ourselves. When we perform a long-continued and ultimately fatiguing task, either physical or mental, we can recognize, with little difficulty, three successive stages of working power, although these are not sharply separated from one another. During the first stage our working power gradually increases; during the second it remains approximately stationary at a high level; during the third it gradually decreases. During the first stage our performance is at first distinctly up-hill work; we find it difficult to concentrate our attention; we feel already fatigued; we could easily give up and do no more. But, surprisingly enough, if we keep on we find the work getting easier; we can accomplish more and more, seemingly without greater effort; we seem to be breaking through barriers that have hindered us; our sensations are agreeable; we say that we are getting our second wind; we feel new courage and no longer care to give up. Before we realize it we have gotten our second wind and have passed into the second stage; our working power is at its best, and we continue to labor, heedless of time; if we attempt to philosophize, we are only conscious of the fact that our labor is easy and our burden light. But this stage, though it may be long continued, ultimately gives place to the third stage when we realize that our powers, after all, are limited, that work is hard, that either we must put forth greater efforts or our output diminishes, and that we are really tired. Now these three stages of individual labor are but the three stages which we have already seen epitomized in the isolated muscle—the treppe, the period of maximum contractions, and the fatigue—and I do not doubt that they are associated with the same chemical phenomena. The stage of getting our second wind is when our fatigue substances are in minute quantity and they gradually augment our physiological irritability and

our output of energy. The stage of our best work is when irritability is at its highest, we have a store of oxidizable fuel, and toxic products have not yet begun to exert their deleterious action. The stage of fatigue is when our fuel is becoming exhausted, its waste products are clogging the furnaces, and physiological irritability is low.

Fatigue, as we feel it after excessive work, is often spoken of as a sensation. Really it is a great complex of sensations. These sensations differ in some degree according to the character of the work, whether it is mental or physical, and if physical, according to the particular groups of muscles employed. But in extreme fatigue such differences are comparatively slight. There may be a "tired" feeling in the head of obscure origin; pain and soreness in the muscles, resulting from an excessive accumulation of blood or lymph, or perhaps from an actual rupture of muscle fibers; stiffness in the joints, resulting from lymph accumulation; swelling of hands and feet, from the same cause; sleepiness, which is accompanied by cerebral anemia; even a feverish temperature because of derangement of the temperature-regulating mechanism; and many other sensations, but, most general of all, a disinclination to perform either mental or physical labor, which may be due in part to general depression of the nervous system, in part to the presence of the unusual sensations, and in part to the mental recognition of the fact that the irritability of our tissues has become diminished and a greater stimulus than before is now required to induce a given action. It is not often possible for the individual to make a satisfactory analysis of the excessively complicated compound of sensations, which he may possess when his body is in a fatigued state. But it has come now to be generally accepted that the sensations

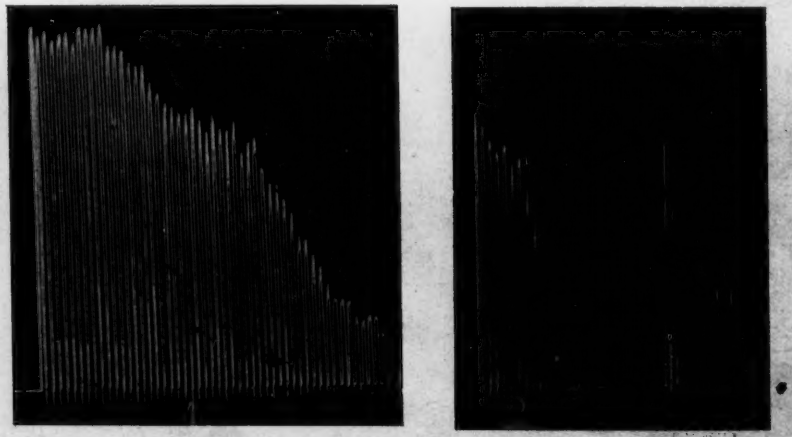

FIG. 6. Series of contractions of the flexor muscles of a human finger. The muscle was stimulated electrically every two seconds, and the resulting contractions were therefore involuntary. Record 1 was made when the muscle was fresh; record 2 immediately after three and one half hours had been spent in the oral examination of students; record 3 two hours after the completion of the examination. (From Mosso's "Fatigue.")

of fatigue result largely from events happening outside of the brain and spinal cord, events of which I have been speaking under the head of physical and chemical phenomena. Such events are not, however, confined to the particular tissues that have performed the fatiguing work, for fatigue substances, though produced in one tissue and fatiguing it, may be carried by the blood to others and there also exert their characteristic action. This fact, that the excessive work of one tissue may cause the fatigue of other tissues, is of great practical importance to us in our daily life. We all believe that excessive muscular work may cause mental weariness. It has been shown by laboratory experimentation that the reverse is true, that excessive mental work may cause muscular weariness. In an experiment upon himself Dr. Maggiora, of Turin, found that the flexor muscles of his middle finger, upon being stimulated by an electric current applied directly to them, were capable of lifting a certain weight fifty-three times before temporary exhaustion set in (Fig. 6). Soon after the completion of the test he entered the class room and devoted the subsequent three and one half hours to the oral examination of students, a task which, he being then a teacher of little experience, was excessively difficult. Immediately after the end of the examination he tested his lifting power again and found his muscles capable of making only twelve contractions. It is often thought that the best means of recuperating after a day's hard mental labor is through the performance of physical exercise. A temporary change of occupation may, indeed, be of great benefit, by relieving an exhausted organ and an exhausted focus of attention. But physiology tells us that a tired brain means a tired body, and that with the brain fagged there is nothing culpable in a desire for not only mental but physical rest.

But there is another aspect of personal fatigue which we can not neglect. Our sensations become our servants or our masters, according as we will. Either we control them, or they control us. Is it legitimate, is it moral, to yield to every sign of weariness? Here we meet at once the problem of the formation of habits. Fatigue may easily become with us a habit, a habit which is destructive to legitimate effort. We have all known the perpetually tired man, the chronically fatigued, to whom both initiative and performance alike are distasteful and to be avoided, when possible. This condition may at times be so pronounced as to be positively pathological, demanding special curative treatment. Fortunately such a condition is rare. Most of us may live on a high or a low plane of activity at will; we may do much or little; we may yield early to fatigue or we may successfully resist it for a time with impunity.

The more one studies physiology the more one appreciates the fact that protoplasm possesses an enormous power of work, and that the human body is endowed with marvelous capacity. Whether we shall

get our second wind, or, having gotten it, whether we shall utilize to the full our powers of work, is a matter of our own will. I believe that few of us live up to our opportunities for accomplishing things. We are too inclined to yield to the early demands of fatigue. Even without exceptional hereditary endowment more of us might have, if we would, the endurance of a Weston, the discernment of a Darwin, the shrewdness of a Harriman, the determination of a Peary, or the insatiate desire to be on top which distinguished our late president. In his very sensible and characteristically delightful essay on "The Energies of Men," William James says:

> The human individual lives usually far within his limits; he possesses powers of various sorts which he habitually fails to use. He energizes below his *maximum*, and he behaves below his *optimum*. In elementary faculty, in coordination, in power of *inhibition* and control, in every conceivable way, his life is contracted like the field of vision of an hysteric subject—but with less excuse, for the poor hysteric is diseased, while in the rest of us it is only an inveterate *habit*—the habit of inferiority to our full self—that is bad. . . . We live subject to arrest by degrees of fatigue which we have come only from habit to obey. Most of us may learn to push the barriers farther off, and to live in perfect comfort on much higher levels of power.

Herein lies the value of training. Training, whether of the child or the adult, the athlete or the thinker, consists largely in the development of a power of resistance to the toxic fatigue substances, and is not unlike the production of a condition of tolerance to a poisonous drug by the administration of successively increasing doses of it. Physical training is not fundamentally different from general educational training. Habits of industry, which every educational system strives to develop in the child, are the converse of habits of fatigue, and in the last analysis habits of industry mean, in very large part, an acquired power of resistance to fatigue substances.

One difficulty which we all recognize is that of distinguishing between real and pseudo-fatigue in ourselves or others, and knowing when a rational degree of real fatigue has been reached. The matter is a vital one to teachers, for a knowledge of the rate at which working power diminishes, of the presence or absence of a fatigue state at a given moment, might be of material help in directing the pupil's work. Various studies have been made of the fatigue of school children, but the results of all of them are unsatisfactory because of the lack of a satisfactory method of investigation. Even the physiologist in his laboratory, however exact he may be with the muscles of animals, has no method of measuring accurately the degree of fatigue in the intact body of a human being. Our sensations are not altogether a safe guide. We often interpret a temporary sleepiness, a temporary lack of power of attention, and uneasiness to be free from our task, as signs of real weariness and evidence that we should stop our labors. Yet we know that often a slight change of conditions will seem to give us renewed

energy, the feeling of fatigue is gone and we turn with freshness to our task; our supposed fatigue was only an illusion. Even with our imperfect experimental methods, however, enough has been discovered to show, among other things, that human beings differ greatly in the rate at which fatigue develops. Mosso demonstrated this many years ago, though his methods are not now regarded as the best.

I have thus far confined myself to a consideration of the nature of fatigue and the conditions under which it develops. Recovery from fatigue is perhaps of even greater interest. Both in the isolated muscle and in the intact organism, fatigue may be carried so far that recovery is difficult or even impossible. The later stages of fatigue are often spoken of as exhaustion, but obviously no sharp line can be drawn between fatigue and exhaustion. Exhaustion is probably most common when labor is continued for years without adequate resting periods. Exhaustion from a temporary effort is of rare occurrence, observable occasionally in athletes and in persons upon whom there is made a sudden and unexpected demand for enormous physical or mental exertion. Usually, however, when a fatiguing expenditure of energy by a living tissue ceases, recovery begins at once. Even in the excised muscle, with all supply of blood cut off, a few minutes' rest allows for a certain degree of recuperation, due possibly to the absorption of oxygen. If a weak solution of common salt, or, better, a suitable mixture of various salts, be passed through the blood vessels of the muscle for a few minutes and thus the accumulated fatigue substances be, at least partially, washed out, the recuperation is greater. If a small quantity of glucose be added to the solution, or if nutritive oxygenated blood be introduced, there is still greater recovery, and the power of further work is much enhanced (Fig. 7). All of these methods are

FIG. 7. Series of contractions of a frog's gastrocnemius muscle *in situ* and stimulated at intervals of two seconds. The flow of blood through the muscle was stopped by ligating the artery, and the record of fatigue was made. At the break in the series, the muscle rested five minutes, during which time the ligature was removed and the blood was allowed to circulate through the muscle. The record of contractions at the right of the break was made immediately after the resting period, and while the blood was still circulating.

physiological—in them the chemical conditions conducing to fatigue are replaced by reverse conditions and the result is reversed—oxygen and food are introduced, carbon dioxide and lactic acid are removed, and there is a restoration of working power. In the living human body

the same processes and the same result are best brought about through the combined agencies of food and rest, with sleep. Sleep is here of value since, by its complete inhibition of the more obvious corporeal activities, it makes rest more complete and thus allows the more complete elimination of fatigue substances and restoration of those things that are essential to future activity.

Equally difficult with the problem of the extent to which labor may safely be carried is the problem of how much food, rest and sleep are required for healthful recuperation. How much we think we require is another question, for here again our sensations are misleading and it is easy to acquire habits which bear little relation to nature's demands. We here assembled, being in the shadow of Professor Chittenden's laboratory, are in the very center of the low-protein camp, and with appetites bridled we can safely defy those who tell us to eat what we please, when we please, and all that we please. There is, indeed, little doubt of the correctness of the main contention of Chittenden, Fletcher, Fisher and their followers, that it is physiologically advantageous to consume less protein than most of the civilized races consume, and it is impossible to avoid a strong suspicion that the presence of a superfluity of food stuffs within the body leads to an accumulation of intermediate metabolic products which in themselves act on the tissues as fatigue substances. The physiological optimum in the matter of quantity of food probably differs with each individual and, with our customarily unscientific habits of judging ourselves, is probably rarely known. This is equally true of the amount of rest and sleep required for recuperation. Our fathers told us "eight hours' work, eight hours' rest and eight hours' sleep"—yet did our fathers, more than we, literally observe the adage? As I believe that most of us eat too much, so I believe that most of us work too briefly and rest too long. Yet more significant than duration is intensity. "Work when we work, and play when we play," is not a meaningless nursery jingle, but a wise physiological dictum. Application, concentration, putting our whole selves into our task, with a wholesome disregard of fancied fatigue—that is the method of accomplishment. But when fatigue really comes, then should the task be laid completely aside for restoration. Play is one of the surest agencies for mental relaxation in the waking state. Pathetic was the confession of one of the world's most busy workers a few years before his death, at the age of forty-five, that he had "almost forgotten how to play." Effective sleep should be dreamless, and if it is of the right sort, it need not occupy one third of all our life. For most persons eight hours of actual sleep would mean nine hours in bed—and only a sluggard would demand that.

Food, rest, play and sleep may be regarded as the effective physiological antidotes to fatigue. One ingenious German investigator would add to these another. In an experimental study he believes that he has

demonstrated in fatigued animals the existence of a fatigue toxin, different from simple carbon dioxide and lactic acid and allied to the toxins produced by bacteria. He claims to have extracted this in a pure form, and upon successive injections of it for a period of time into the bodies of other animals their tissues have produced, he claims, an antidote to it in the form of a real antitoxin. This antitoxin of fatigue, if administered to fatigued animals or even human beings, is said to bring about prompt recovery; if administered to fresh organisms it is said to greatly prolong their working period. I am not prepared to deny the truth of these claims, but such striking discoveries should be confirmed by other investigators before one can fully believe in their reality. It may be said that present science knows no safe, quickly acting, effective antidote to the toxic action of fatigue substances. There can be no doubt, however, about the temporary anti-fatiguing power of certain drugs. The caffeine of coffee and tea is one of these, and the theobromine of cocoa is another. Alcohol, too, may act as a temporary whip. When administered to even an isolated muscle, in small quantity, it augments activity, quickens contraction and delays fatigue; in large quantity it is depressing and hastens fatigue. In these respects alcohol is not unlike the physiological fatigue substances. It is undoubtedly useful in very brief emergencies involving fatiguing effort, but like other drugs its usefulness lies outside the normal physiological life of the individual.

Besides the more purely physiological and psychological aspects of fatigue, it has an important relation to many sociological problems. In its milder form it may be regarded as a blessing, since it leads to healthy rest. But if its warnings are not heeded, it may prove a serious affliction. By reason of its inhibition of activity it is a potent sociological force. It is one of the causes of misery and poverty and disease; it is an inciter of crime; it has helped to lose battles; it has limited industrial expansion. Professor Irving Fisher has recently estimated the minimum annual cost of serious illness in this country as one and a half billion dollars, and says: "The economic waste from undue fatigue is probably much greater than the waste from serious illness." Fatigue must be reckoned with in all human activities, and its toll must be rigidly paid. Happy is he who has the power so to direct his bodily machine as to obtain from it its highest efficiency.

A GREAT MARINE MUSEUM

By Professor CHARLES ATWOOD KOFOID
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A LOGICAL and characteristic expression of the national spirit of modern Germany is to be found in the Institut für Meereskunde which was established in 1900 in connection with the Königliche Friedrich-Wilhelms Universität at Berlin. The rise of Germany as a maritime power has found popular demonstration in the Marine Expositions at Berlin in the winter of 1897–1898 and again in the summer of 1908. The first exposition led to the beginning of a permanent marine museum and the second contributed greatly to its expansion. In 1898 the German Naval Bureau together with the Prussian Cultus Ministerium undertook the establishment of an oceanographical institute in conjunction with some Prussian university, plans for which were drawn up by Professors E. v. Drygalski and E. v. Halle with the later assistance of Freiherr v. Richthofen. The enterprise had from the beginning the deep personal interest and cooperation of the German Emperor. It finally took the form of the Institut für Meereskunde of which Professor Albrecht Penck is director.

In 1906 the Museum für Meereskunde connected with the Institut für Meereskunde was opened in the building on Georgenstrasse, formerly occupied by the chemical laboratory of the university. The purpose of the museum has been stated by its director to be "to inspire and to diffuse far and wide in the German nation by means of its exhibits a conception and understanding of the sea and its phenomena, the means employed in its exploration, the wealth of its life, and its economic value, as well as the social and national significance of navigation, marine commerce and sea power." "Deutschland zur See" is its motto!

This end has been sought by the almost lavish installation of exhibits which reveal everywhere the combination of technical skill and broad scientific knowledge and direction, together with a remarkable freedom from conventional methods in design and execution of the displays.

The exhibits are found on the two lower floors of the building and offices, library and laboratories are on the third floor. The whole of the first floor and part of the basement are given up to a most varied and elaborate display of the German naval and marine interests along historical, structural and mechanical lines. The second floor contains

FIG. 1. EXHIBIT OF APPARATUS FOR DEEP-SEA EXPLORATION, sounding machines and bottom samplers.

the exhibits of harbor construction, light houses and life-saving equipment, and the scientific departments of special interest to those concerned in marine investigations.

The first of these is the collection of nautical and oceanographic instruments and the oceanographic exhibit. The collection of charts, compasses, sextants, chronometers, clinometers and ship's logs is extensive. In adjacent rooms, 3 to 6, are to be found a most excellent and an almost historically complete collection of the instruments devised for deep-sea exploration. Sounding leads, pressure tubes and bottom samplers from the time of the expeditions of the *Challenger* (1873–

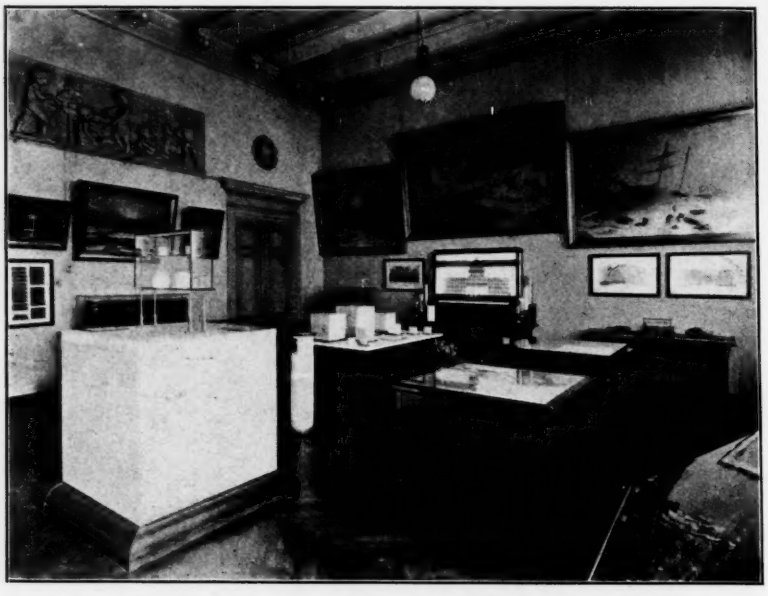


FIG. 2. OCEANOGRAPHICAL EXHIBIT.

1874) and the *Gazelle* (1874–1876) down to all the varied patterns from the ships of the cable construction companies and recent deep-sea expeditions, are here displayed together with sounding wires, cables and weights, sounding machines of various types—Thomson, Lucas, Sigsbee, LeBlanc and others—exhibited either by photographs and diagrams, or as actual instruments. There is also a display of typical bottom samples as collected by the merchant marine.

The study of the physical and chemical conditions in the sea is elucidated by a unique collection of instruments. Pressure and reversing thermometers of the Six, Chabaud, Miller-Casella, Negretti-Zambra, Knudsen, Richter and other types are shown, together with instructive exhibits of the effects of pressure at great depths in the sea in crushing thermometers. Scales for recording the color of the sea water and apparatus for determining its transparency are exhibited near the windows of the room. The apparatus used in determining specific gravity and salinity is also found here; self-closing water-samplers of the Meyer, Sigsbee and Petterssen-Nansen patterns for bringing up water from any desired depth without contamination from other levels, areometers, pycnometers and apparatus for chlorine (Knudsen) and gas (Fox) analysis.

In an adjacent room are meteorological instruments together with an exhibit of hydrographical instruments such as drift bottles, wave meters, tidal registers and current meters of Aime-Irminger, Massee, Arwidson, Nansen, Ekman, Petterssen bifilar and other patterns for submarine exploration.

The collection of biological gear and tackle is much less complete and less advantageously displayed. There are samples of dredges, tangles, trawls, tow-nets, plankton nets, plankton nets of the Hensen, closing-net of Nansen and young-fish net of the Helgoland pattern.

The oceanographical exhibit in rooms 8 and 9 is original in design and execution and contains unique and instructive displays designed to facilitate by comparative methods the quick and easy comprehension of the fundamental facts of oceanography. Marble blocks are used to represent the relative volumes of the globe, the sea, the land above sea-level, and in the continental blocks (above 2,300 m. below sea-level). In a similar way their relative weights and those of the atmosphere and of the dissolved salt in the sea are shown, as are also the quantity of salt and the proportions of the various substances dissolved in sea water. A very striking illustration of the quantity of salt in the sea is shown by a comparison, to scale, of the thickness of the crust left on the sea bottom on evaporation of the sea, with a model of the royal castle at Berlin to the same scale. The relative elevation of the continents and depths of the seas are shown by plastic reliefs. Models of a transatlantic liner on columns of blue glass bring in vivid contrast the conditions as to depth in the North Sea, the Atlantic and the greatest known ocean depths. Movable mechanisms illustrate wave motion, while the effect of breakers on steep and flat coast line is shown by photographs and examples of erosion.

The biological exhibits are striking in their design and educative in purpose. There is little attempt at a systematic exhibit of marine

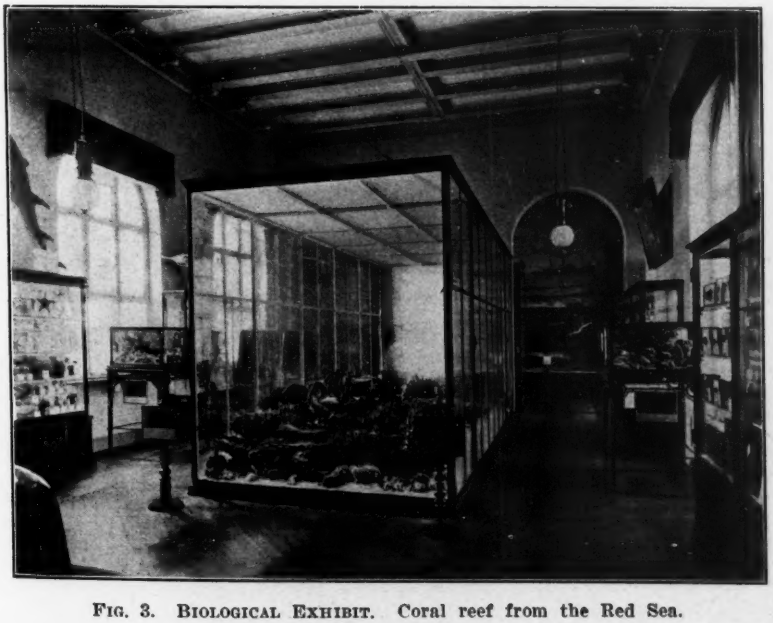


FIG. 3. BIOLOGICAL EXHIBIT. Coral reef from the Red Sea.

forms, the whole of the selection and grouping of the collections being subordinated entirely to securing a representation, as nearly normal as possible, under the limitation of space and conditions of the material, of the characteristic assemblages of marine animals and plants. Numerous tanks of considerable size contain displays of faunal types, in alcohol or formalin, in natural groupings and environmental effects. Dried collections and the taxidermist's art are also used in larger exhibits, as, for example, in a most excellent portrayal of a coral reef from the Red Sea. Ten small "alcoholaria" give vivid pictures with much of the original color preserved, of the minor types of faunal assemblages about a coral reef, such as the sea urchins and sea roses (*Crambactis*) with symbiotic fish (*Amphiprion*); giant mussels (*Tridacna*), corals and parrot fish; the madrepore area; the rock fauna; the regions of dying and of dead corals and the plant life of coral reefs. In like spirit and perfection of technique are displayed the fauna of the Antarctic icebergs, the sponge beds of the Ægean Sea, the fishing grounds off Helgoland, the pelagic world, the sandy grounds, the rock pools, oyster beds, limestone cliffs and the fishing banks of the North Sea.

The ecological interrelations of the marine fauna are suggested by exhibits of the food of well-known fish. The economic values and uses of the products of the sea are concretely illustrated in striking manner by transparencies, and by exhibits of the crude materials and various

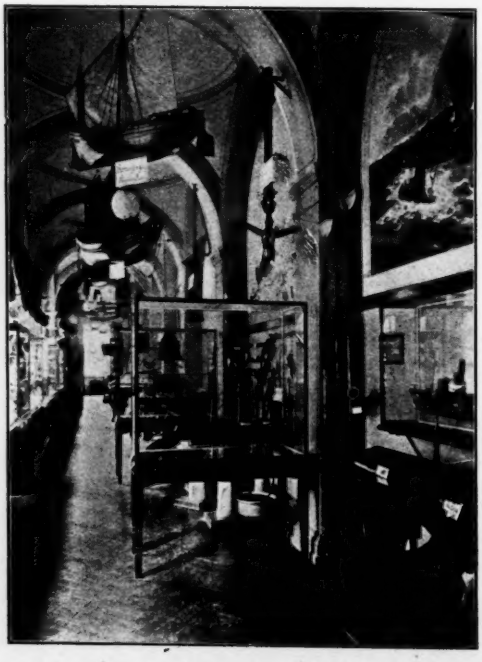


FIG. 4. ECONOMIC EXHIBIT. Whale fisheries and their products.

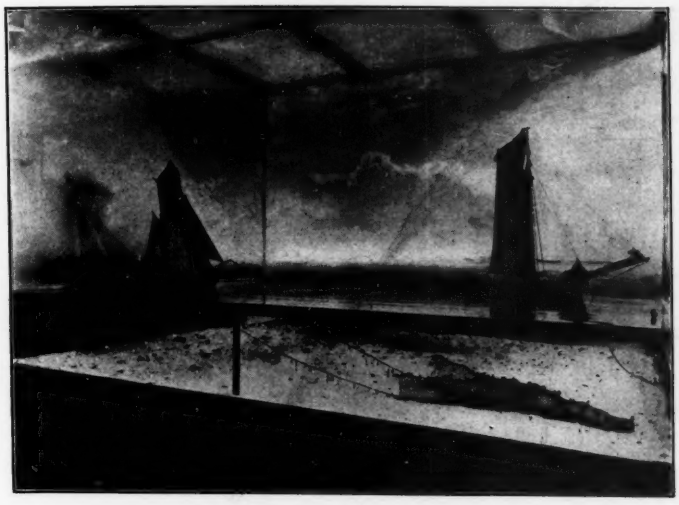


FIG. 5. MODEL OF NORTH SEA TRAWLER AT WORK ON FISHING GROUNDS.

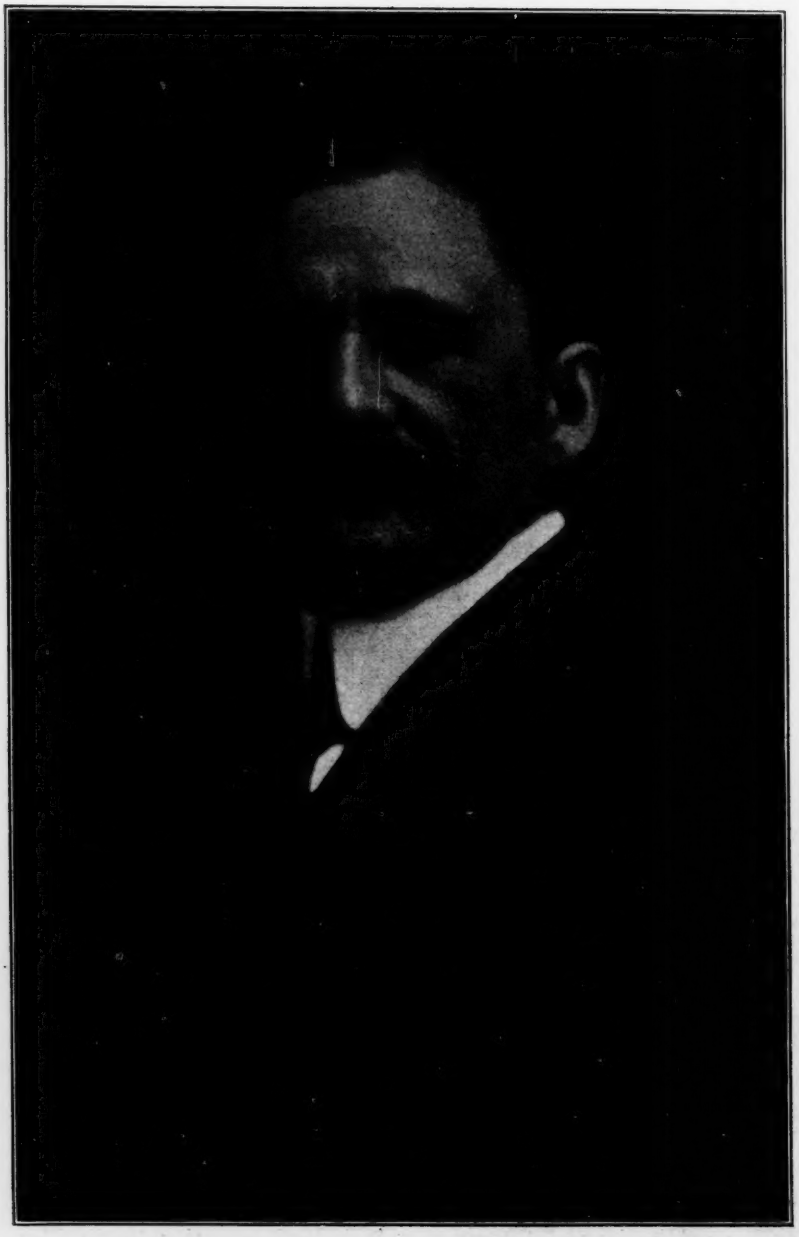
stages in their manufacture into the finished products of art or industry.

The fisheries section is rich in well-displayed exhibits of most of devices known to man from the earliest times to the present, for the winning from the sea its rich booty; examples of gear and tackle, photographs, transparencies and oil paintings of their use, models showing boats and fishery gear in action, and the homes of fisher folk.

The wonderfully rich and exceedingly varied exhibits of this museum, centered as they are around the idea of the utilization of the sea, that least-known and last-to-be-conquered part of the globe, give even to the museum-weary traveler a new and inspiring conception of the magnitude and diversity of the resources of the sea and the complexity and attractiveness of the national, commercial, industrial and scientific problems connected therewith.

That the museum has accomplished its purpose in stimulating popular interest and enthusiasm in marine matters is attested not only by recent German political history but also by the 100,000 persons who thronged its rooms in the first year it was opened to the public and in the interested groups of visitors who still frequent its halls. The exhibits are free to the public, special days are reserved for classes, photographing and sketching are encouraged, and popular lectures are given on subjects allied to the purposes of the museum, for which a very extensive collection of lantern slides has been made.

The publications of the museum include, in addition to the illustrated guides, a popular series of "Meereskunde, Sammlung volkstümlicher Vorträge zum Verstandnis der nationalen Bedeutung von Meer und Seewesen," twelve parts yearly from 1897 and a more formally scientific series "Veröffentlichungen des Instituts für Meereskunde und des Geographischen Instituts an der Universität Berlin."



PROFESSOR A. A. MICHELSON,

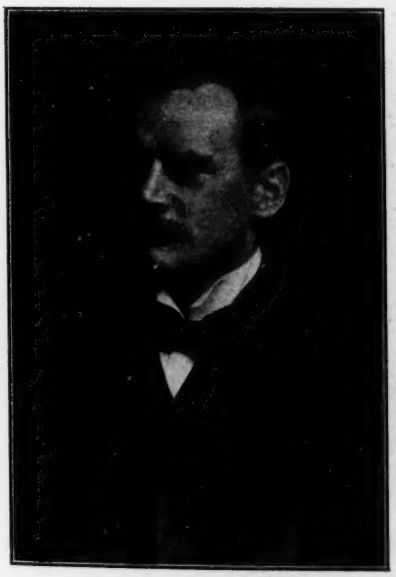
Head of the Department of Physics in the University of Chicago. President elect of the American Association for the Advancement of Science.

THE PROGRESS OF SCIENCE

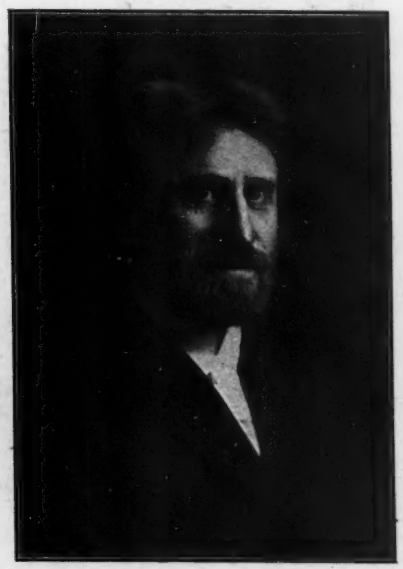
THE CONVOCATION WEEK MEETING AT BOSTON

THE meeting of the American Association for the Advancement of Science and the national scientific societies affiliated with it held at Boston during the week following Christmas was as large and important as any gathering of scientific men that has hitherto taken place in this country. The registration of members of the association was 1,140 as compared with 975 in Washington in 1902, 890 in Philadelphia in 1904, 934 in New York in 1906, 725 in Chicago in 1907 and 1,088 in Baltimore in 1908. From this voluntary registration it is difficult to estimate the attendance of scientific men. 200 chemists registered as members of the association and 558 as members of the American Chemical Society. Should a similar proportion have obtained in the other sciences, the number of scientific men would have been in the neighborhood of 3,000. It was probably not so great as this, but well above 2,000.

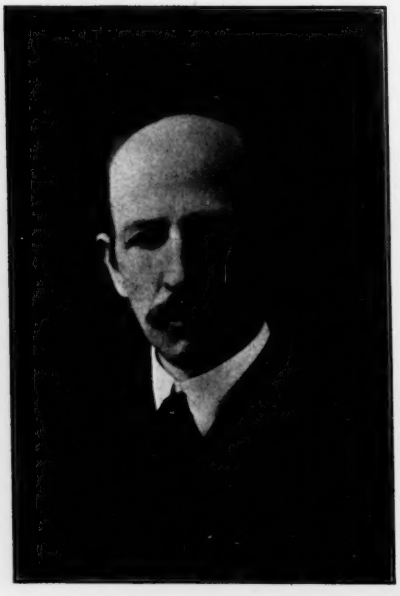
Although Boston is at the northeast corner of the field of scientific activity of the United States, it is still central, through the magnitude of its educational and scientific work and on account of its easy accessibility from other centers. Harvard remains our leading university and the Massachusetts Institute our leading school of technology, although the gap between them and other institutions is closing, and their supremacy may not be unchallenged when the association next



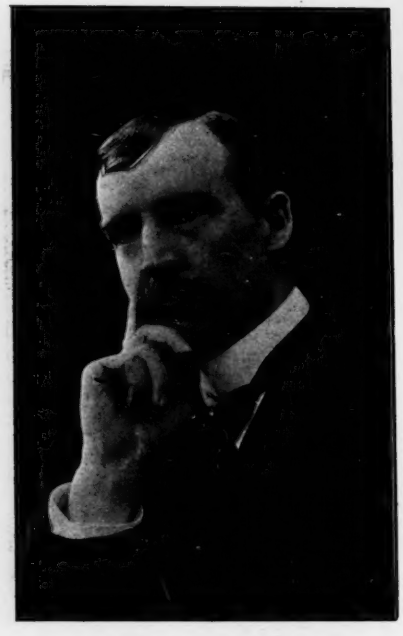
DR. ERNEST W. BROWN,
Professor of Mathematics in Yale University, Vice-president for Astronomy and Mathematics.



DR. L. A. BAUER,
Director of the Department of Research in Terrestrial Magnetism, Carnegie Institution, Vice-president for Physics.



DR. WILLIAM MCPHERSON,
Professor of Chemistry in Ohio State University, Vice-president for Chemistry.



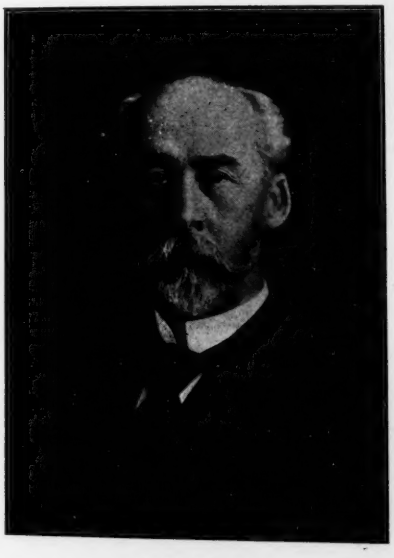
DR. D. P. PENHALLOW,
Professor of Botany, McGill University, Vice-president for Botany.

meets in Boston. All arrangements were admirably made, though it was in some respects unfortunate that it was necessary for the sections of the association and the different societies to meet at widely separated places. The hotel selected for headquarters was somewhat small for a general meeting place, and the office of registration in the Technology Union, while a pleasant meeting place, was too isolated. In-

R. W. BROCK,
Professor of Mining, School of Mines, Kingston, Can., Vice-president for Geology.

deed it may be said that while the meetings of the special societies were admirable, the efforts made by the general association to provide meetings of general interest and to bring together men of science working in different departments were only partly rewarded. The addresses and programs were in most cases excellent, but the scientific men in attendance were occupied in their special societies, very few members of the association not engaged in

scientific work attended the meeting and the citizens of Boston probably find the city already saturated with lectures and addresses. At the meetings of the British Association there are usually a thousand or more local members elected for the meeting who provide large audiences. The difference is doubtless largely in the social organization of society; but it is unfortunate that the American Association is able to do so little to give science the dominant place it should have in the life



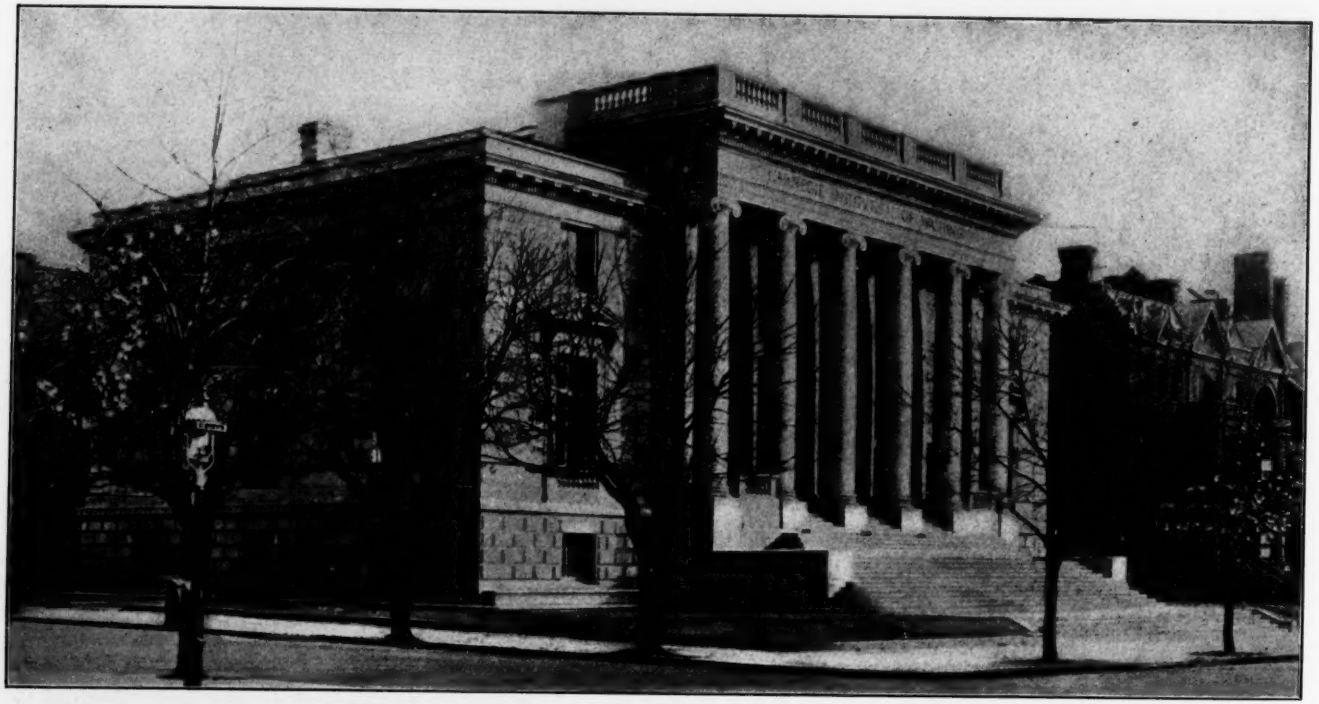
W. H. HOLMES,
Head Curator of Anthropology, U. S. National Museum, Vice-president for Anthropology.

of the people. All those who realize the importance of this problem should unite to do what they can to keep the larger public in touch with the advance of science.

It is almost bewildering to consider that the titles of more than a thousand scientific papers were printed on the preliminary program. They were distributed among the sciences included in the association, as follows: astronomy and mathematics, 37; physics, 54; chemistry, 254; mechanical science and engineering, 17; geology and geography, 141; zoology, 124; botany, 122; anthropology and psychology, 63; social and economic science, 17; physiol-

DR. JAMES E. RUSSELL,
Dean of Teachers College, Columbia University, Vice-president for Education.

DR. W. G. SUMNER,
Professor of Political and Social Science, Yale University, Vice-president for Economic and Social Science.



ADMINISTRATION BUILDING OF THE CARNEGIE INSTITUTION OF WASHINGTON.

ogy and experimental medicine, 166; education, 30. Chemistry is thus by far the best represented of the sciences, and social and economic science the weakest. The former fact is in part accounted for by the industrial applications of chemistry, but it also represents efficient organization and close affiliation between pure and applied science. There must be nearly as many men engaged in physics and its applications, but the number of papers was only a fifth as large. Economics and sociology are not adequately represented at the meetings of the association because the national societies concerned with these subjects are meeting elsewhere.

Dr. T. C. Chamberlin, the retiring president, in his address given in Sanders Theater of Harvard University on the first day of the meeting was able to select a topic on which he is the leading expert authority and which is of broad human interest. The address was entitled "A Geologic Forecast of the Future Opportunities of our Race" and reviewed the relations of the nebular hypothesis and his own planetesimal hypothesis of the origin of the solar system and the earth to the geological history of the earth and the life on it. The newer theories give the earth a long past in which life has been supported and a long future in which it can be supported not seriously threatened by catastrophies. The highest development and the greatest longevity of the race depend mainly on moral purpose and the resources of research which now for the first time are being clearly manifested.

The president of the meeting, President David Starr Jordan, of Stanford University, eminent equally as a zoologist and for his services to education, handed on the office to Professor A. A. Michelson, of the University of Chicago, one of the world's great physicists, according to the awards of the Nobel prizes the most eminent scientific man of America. He will preside at the meeting to be held next year at Minneapolis and will give the annual address at the meeting to be held the following year at Baltimore. We are able to reproduce his portrait and the portraits of the vice-presidents of the Baltimore meetings, as it is worth while to make the acquaintance even through a picture of those who hold an office which indicates both activity in research and leadership in scientific organization.

DEDICATION OF THE ADMINISTRATION BUILDING OF THE CARNEGIE INSTITUTION OF WASHINGTON

THE Administration Building of the Carnegie Institution of Washington, situated on the southeast corner of Sixteenth and P Streets, Washington, D. C., was dedicated December 13, 1909. The brief ceremonies of the occasion were conducted in the assembly room of the building. Dr. John S. Billings, chairman of the board of trustees, presided; an account of the origin and development of the institution was given by Hon. Elihu Root, vice-chairman; and remarks in appreciation of the work already accomplished by the institution were made by Mr. Andrew Carnegie, the founder. Professor George E. Hale, director of the Solar Observatory of the institution, then gave a lecture by aid of lantern illustrations of the work already done in his department of investigation.

At the close of these exercises the trustees and guests were invited to inspect exhibits of the ten departments of investigation and of the divisions of publication and administration, installed in the rooms on the uppermost floor of the building. During the conversazione which followed refreshments were served on the main floor of the building. Since the assembly room will seat only about two hundred people, the lecture of Professor Hale was repeated during the afternoon of the following day for the benefit espe-

cially of the members of the departments of investigation quartered in Washington and for the benefit of interested guests from government bureaus.

During the afternoons of the three following days the building and the exhibits above referred to were open to inspection by the public. About two thousand people availed themselves of these opportunities. For the benefit of friends and guests of the institution, a souvenir pamphlet giving in brief the plan and scope of the institution and some indications of its development up to date had been prepared, and a copy of this was furnished to each visitor.

SCIENTIFIC ITEMS

WE regret to record the deaths of Dr. Charles B. Dudley, chief chemist of the Pennsylvania Railroad Company, and Dr. Ludwig Mond, F.R.S., the distinguished industrial chemist.

IT is proposed to add to the collection of portraits of deceased members of the American Philosophical Society that of Professor Simon Newcomb. The formal presentation of the portrait is expected to take place in connection with the annual meeting in April.

MR. WILLIAM H. HOLMES, chief of the Bureau of American Ethnology, on January 1 severed his official connection with the bureau and resumed his place as head curator of anthropology in the U. S. National Museum, and in this connection also became curator of the National Gallery of Art. Mr. F. W. Hodge took charge of the Bureau of American Ethnology with the title ethnologist in charge.—Dr. C. F. Chandler, since 1864 professor of chemistry in Columbia University, will retire from active service at the close of the present academic year.

THE Chicago Geographical Society has awarded the Helen Culver gold medal to Commander Robert E. Peary, for distinguished services in exploration, and to Professor Thomas C. Chamberlin, of the University of Chicago, for distinguished services in geographical research.

MRS. RUSSELL SAGE has given Yale University $650,000 to pay for the Hillhouse property.—Mr. Henry Phipps, founder of the Phipps Institute in Philadelphia, has presented to the University of Pennsylvania $500,000, to be used in the campaign against tuberculosis. The management of the Phipps Institute will be placed in the hands of the university.—Mr. Otto Beit has given to the University of London £215,000 to endow fellowships for medical research.